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EFFECT OF CLAY AND LOAM ON CEMENT MORTAR.

By C. E. Sherman.*

During the summer of 1900 the writer was called on to take charge of the construction of the concrete viaduct illustrated in the accompanying engraving. This bridge is situated on the north wall of Glen Creek Canon, four miles from Mammoth Hot Springs, in Yellowstone National Park, the bridge site being better known as the Golden Gate. A stage road winds through the canon on a bench on the north wall for a distance of nearly a half mile. This bench is broken at places, and at the point illustrated is missing for 200 ft., the roadway formerly being carried here in an old and dangerous wooden trestle, perched on the ragged projections of the cliff.† The new bridge, replacing the old trestle, is built entirely of gravel concrete, Atlas Portland cement being used, and is 200 ft. long by 16 ft. average width. It is curved to a radius of 573 ft. at the outer edge, and is on an 8% grade.

VIEW OF CONCRETE HIGHWAY BRIDGE AT THE GOLDEN GATE, YELLOWSTONE NATIONAL PARK.

During its construction some interesting questions arose; among them was this one, What percentage of clay or loam may be allowed in cement mortar? Clean material could not be found nearer than four miles from the bridge site, and that at a place nearly 1,000 ft. lower in altitude. Plenty of earthy sand and gravel, which would be suitable if washed, could be had upon the plateau above the canon, but owing to the scarcity of water, and the location of the bridge the cost of washing was prohibitive. After considerable exploring on the flat above, a bed of fairly clean material was found, at about a mile from the bridge, underneath an old pit used previously for road metal. This material, containing about 3% to 7% by volume of alkaline earth, organic matter, etc., was used, without washing, in the bridge.

Upon the completion of the work, some briquettes made of cement and earthy material, as used, showed a higher tensile strength than briquettes of the same material after washing. To test the matter further, from May, 1902, until May, 1903, a series of tests was carried on under the writer's direction by Messrs. E. H. Ames and Adolph Stellhorn,* and the following abstracts from their thesis gives the results:

It has been the custom to specify that sand should be clean, sharp and coarse for use in cement mortars in masonry structures. Great precautions are sometimes taken to see that these specifications are enforced. The contractor has thus been forced in many cases to go to quite an expense to come up to these requirements. The present investigation is to determine whether or not a moderate proportion of clay or loam is injurious to cement mortar, and the experiments cover an entire year, the supposition being that any combination of cement, sand or loam that stands the test for this length of time is reliable.

What would be the limiting per cent. of loam or clay that would not affect the mortar, as far as strength or weathering properties are concerned, has not been determined, although the tests run up to 15% of clay or loam. This will include nearly all natural sands, as one will seldom be found containing 15% of these materials.

MATERIALS.—The cements used in this work were the Dyckerhoff and Lehigh, these being taken as fair representatives of the imported and domestic Portland cements.

The Dyckerhoff cement tested as follows: Strength as shown by the diagram in Fig. 1; weight—78 lbs. per cu ft.; activity—Initial set one hour and five minutes, final set three hours and thirty minutes; fineness—On a No. 50 sieve 1/8% remained, on a No. 74 sieve 4 3/8% remained, on a No. 100 sieve 2.6% remained, and on a No. 200 sieve 18.4% remained. The cement showed no signs of unsoundness.

The Lehigh cement gave the following results: Strength as shown by Fig. 1; weight—80 lbs. per cu. ft.; activity—Initial set two hours and ten minutes, final set six hours and thirty minutes; fineness—On a No. 50 sieve 0.25% remained, on a No. 74 sieve 6.5% remained, on a No. 100 sieve 4.0% remained, on a No. 200 sieve 13.5% remained. The cement showed no signs of unsoundness.

TESTS.—The cement was allowed to fall 3 ft. into a box holding 1-10 cu. ft., and ten times this was taken as the weight per cubic foot. The cement and water were worked for five minutes and then placed on clean glass plates, time being taken from the moment the water was added. Initial set was taken when a needle weighing ¼-lb. and 1-12-in. in diameter made no impression on the pat. Final set was taken when a needle weighing 1 lb. and 1-24-in. in diameter made no impression on the pat. The test for fineness was made with standard sieves. These were used in a machine which gave about 240 strokes per minute. No shot or coins were used. Soundness we tested by letting pats set on clean glass plates for 24 hours; then keeping them in steam for three hours, after which they were boiled for three hours. Cold tests were also made. Neither cement showed any signs of unsoundness.

SAND.—Three kinds of sand were used, lake, bank and crushed quartz. The lake sand was from Sandusky, O., on Lake Erie. It weighed 105 lbs. per cu. ft. The voids were 40%. This sand all passed a No. 30 sieve. Bank sand was from the Mock sand banks located in Franklin County, Ohio. It weighed 102 lbs. per cu. ft. The voids were 40%. This sand passed a No. 12 sieve and was

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†For description of new and old bridge, see Report of Chief of Engineers, U. S. A., for 1901. Appendix FFF; H. M. Chittenden, Capt. Corps of Engineers, officer in charge.

*Graduating students from the Civil Engineering Department, Ohio State University.

washed before using in briquettes. The standard sand was the Am. Soc. C. E. standard.

CLAY.—The clay was Mayfield Ball clay from Mayfield, Ky. The clay was first dried and then ground in a ball mill. The fineness could not be determined, as the clay packed in the sieves. It was probably as fine, if not finer, than the cement. Briquettes of clay were made, but would not get hard under water, showing that they had no hydraulic properties.

LOAM.—The loam was common field soil obtained from the filed north of the power house on the State University campus. This was also ground in the same way that the clay was. It was also tested for hydraulic properties, but found to have none.

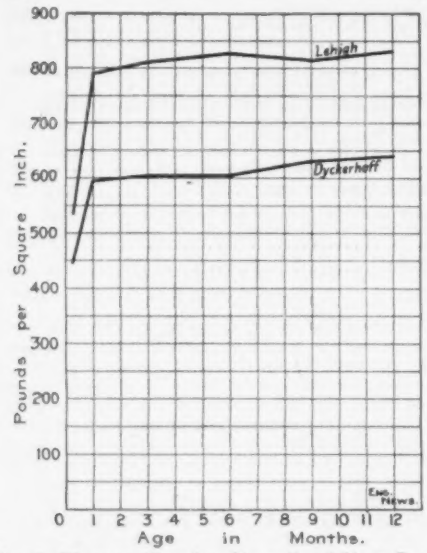

Fig. 1. Diagram Showing Strength of Neat Dyckerhoff and Lehigh Portland Cements for Testing with Clay and Loam Mixtures.

METHOD OF PROCEDURE.—In mixing the mortar the proportion of one part of cement to three parts of sand was used. Where clay or loam was used it was taken as a per cent. of the sand, and in this way the proportion of one to three was maintained, all proportions being by weight. The materials after being properly weighed were put on a glazed paper and thoroughly mixed while dry. The mixture was then placed on a smooth slate slab, a small crater was made in the top of the pile and in this was put the water; 10% water was used for 1-3 mixtures and 20% for neat. This was then mixed until the consistency was uniform throughout the mixture. The mortar was then put in the molds (five specimens of each being made) in three layers, each being tamped with a wooden tamper about ¾-in. in diameter.

All briquettes were given as nearly as possible the same amount of tamping. The tops were then struck off level, and each set given a number, consequently each number in the table* is the average of the five briquettes. As soon as these were set hard enough, they were taken from the molds and placed under damp cloths and allowed to remain for 48 hours. (The briquettes with high per cent. of loam and clay were put under water after 24 hours had not set enough, and sloughed away. So, for uniformity, all briquettes were allowed to remain 48 hours in air.) They were then put in water. The 26, 39, 52-weeks briquettes were put in large boxes and placed in the reservoir by the University power house. They were thus subjected to the varying temperature of Central Ohio for these periods. The 1, 4, 8, 13-weeks briquettes were placed in tanks in the laboratory, the temperature of which ranged from 60° to 70° F. The water was changed twice a week.

The briquettes were made of the form adopted by the American Society of Civil Engineers. Tests were made for each combination of cements and sands, and for each combination of cements, sands, and clay or loam for 1, 4, 8, 13, 26, 39 and 52 weeks.

The testing machine was a late model shot machine made by the Fairbanks Co.

In the following diagrams the curves were plotted for age in months, to make them comparable with other long tests, which are usually given in months:

Arranging the diagrams in the order indicated below some interesting conclusions may be drawn:

Lehigh. Bank Clay	Dyck. Bank Clay	Lehigh. Standard Clay	Dyck. Standard Clay	Lehigh. Lake Clay	Dyck. Lake Clay
625	560	550	600	500	425
1	2	3	4	5	6
Lehigh. Bank Loam	**Dyck. Bank Loam**	**Lehigh. Standard Loam**	**Dyck. Standard Loam**	**Lehigh. Lake Loam**	**Dyck. Lake Loam**
650	550	525	450	450	400
1	2	3	4	5	6

In the above table the first three lines give the composition of the briquettes. The fourth line is the position of an average of the set of curves at the twelve-month point. The fifth line is the relative strength of the combination.

It is seen that the strength of the clay and the loam briquettes are almost the same. Also the Lehigh cement tests stronger than the Dyckerhoff in each combination, as it did in the neat briquettes (Fig. 1). The bank sand also proved stronger in each combination than either the standard or lake sands.

In 72 curves representing cement, sand, clay or loam, only five fell below the zero per cent., and the 15% mixture of clay and loam proved to be the stronger at the end of one year in eight cases out of twelve. It seems reasonable to conclude, therefore, that clay or loam up to 15% is beneficial to cement mortar. However, the disadvantage of using a high percentage of loam or clay in mortars to be immersed, must be kept in mind. If the mortar is to be placed immediately under water, more than 8% would cause some trouble, as it takes longer to reach its final set.

It would appear from the diagrams that short time tests up to a period of three months are of minor value in comparing the relative strength of cement mortars, the longer time tests giving much more uniform results.

As to whether the strengths of the mortars tested is permanent or not, we think that since it has shown no tendency to drop in one year, and in most cases the curves have taken the horizontal position, it is safe to say that it is permanent.

The above experiments were carefully conducted and the conclusions were drawn, not from one set of lines, but from an average line for each diagram. The Golden Gate Bridge has now well withstood for three years the extremes of climate of our National Park, showing that the earthy material has not affected the weathering properties of the concrete there. In the Transactions of the American Society of Civil Engineers, Vol. XIV., p. 165, Mr. E. C. Clarke reported that 10% of loam, used with clean sand and Rosendale cement, did not decrease the strength after six months or a year. He found that some 350 briquettes of Portland cement were not weakened by clay in moderate quantities, nor were their weathering qualities impaired in 2½ years.

The writer is satisfied that time and money spent in washing sand for Portland cement concrete is wasted, and that the importing of lake sand, frequently specified at many places, is often unnecessary. The insurance of a clean aggregate is of much more importance, especially if the concrete may be subjected to a tensile stress.

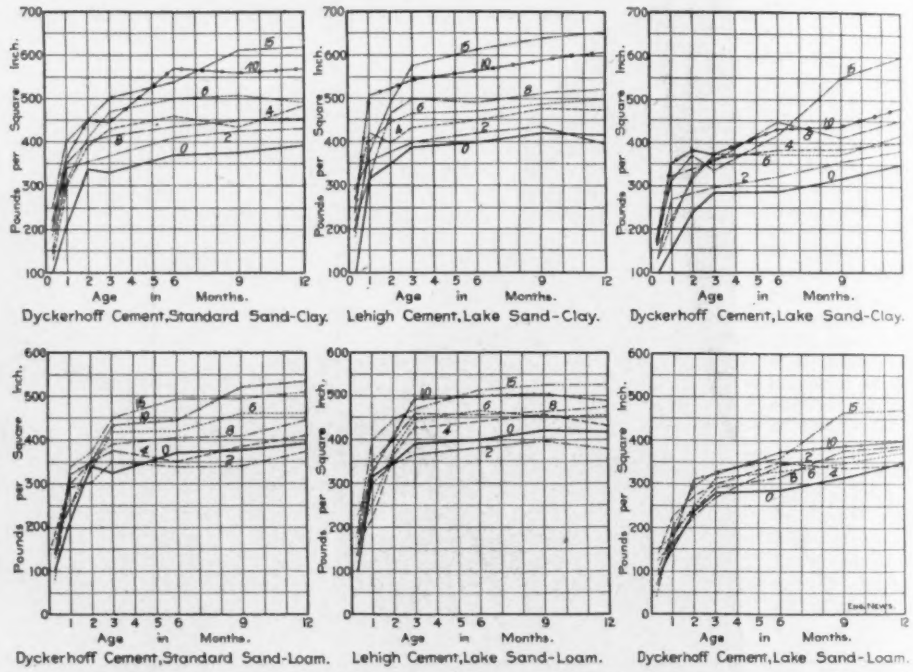

FIG. 2. DIAGRAM SHOWING EFFECT ON PORTLAND CEMENT MORTAR OF DIFFERENT ADMIXTURES OF CLAY AND LOAM.

Figures on Curves Denote Percentage of Loam or Clay.

A COMPARISON OF THE REQUIREMENTS OF RECENT RAILWAY BRIDGE SPECIFICATIONS.

By A. H. Heller.*

In the accompanying table the writer presents a comparison of some of the requirements of a number of railway bridge specifications. The names of the railways are not given, since the specifications compared were secured for another purpose, and because it was thought that their omission would not detract materially from the value of the comparison. It should also be noted that it is impossible to give, in such a summary, the full and complete requirements of each specification. One of them, for example, gives 20 unit stresses for steel and 35 for iron. Such information is given as was thought most valuable for purposes of comparison.

Such a comparison as this I consider valuable in that it shows to what extent certain movements, such as increase of train loading, have been carried; to what extent the judgments of engineers differ; and to what extent practices are uniform. No doubt, many engineers will see the desirability of more uniformity in many requirements, but a complete uniform standard for all railway lines would be as impossible as it is undesirable. That there is as much uniformity as there is, is probably due to the fact that few engineers have the time to make original investigations, and therefore follow previous practices and often use, in their specifications, the exact phraseology of some older specifications. There are very few original specifications.

Referring to the accompanying table, there will be found a summary of such requirements as depend mostly on the engineer's judgment, and in which there is, therefore, the least uniformity. The list covers 32 specifications; 4 of these cover only material and workmanship; 28 cover designing also. There are included three general specifications, namely, those of the American Bridge Co., of the Osborn Co., and Theo. Cooper's; one Canadian railway specification; one Mexican railway specification, and 27 of the most important railway systems in the United States. Except for material and workmanship, the comparisons will be between 28 specifications.

SIZE.—The widths vary from 5⅜ to 8½ ins., and the lengths from 9 to 17 ins.; 14 are nominally 8½ × 14 ins., and 5, nominally 6 × 9 ins.; 13 are of various odd sizes. There would seem to be no doubt that those bound in book form are the more convenient. There are twelve of this kind. A few are well arranged, having a table of contents and being well cross-referenced.

DATE.—The dates of the specifications indicate how generally they have been rewritten within the last five years.

KINDS OF BRIDGES.—I-beam spans and trough floors are used for lengths up to from 20 to 34 ft. Girders are used for lengths, from the shortest up to 130 ft. Lattice trusses are used for lengths between 60 and 180 ft. Pin-connected

*Not printed.

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trusses are used for lengths greater than from 106 ft. to 180 ft. The practice may be said to be about as follows: I-beam spans up to 20 ft.; plate girders, from 20 ft. to 100 ft.; lattice trusses, from 100 ft. to 150 ft.; and pin-connected trusses for spans over 140 ft. The steady movement, for some years, toward rigid construction, has notably increased the use of plate girders and riveted trusses.

CLEARANCE.—Ten out of 27 specifications require a greater clear width than the old standard of 14 ft. Seven require 15 ft.; one, 16 ft., and one more than 16 ft. (20 ft. c. to c. of trusses). Ten out of 26 specifications require a clear height of 22 ft.; 4 of 21½ ft.; 4 of 21 ft.; 3 of 23 ft.; 2 of 20 ft.; 1 of 20½ ft.; 1 of 23½ ft.; and 1 of 25 ft. Some of these heights are measured from the top of the rail and some from the base.

In the majority of cases, the clear height is required for a width of 6 ft. at the top and 10 ft. at the bottom, the maxima being 8 ft. and 11 ft., respectively. The clear height, at the sides, may be reduced from 4 ft. to 6 ft. at the top, and from 1 ft. to 3 ft. at the bottom, the majority specifying 5 ft. at the top and 4 ft. at the bottom.

DEAD LOAD.—The weight of track is generally assumed to be 400 to 450 lbs. per lin. ft., including rails, ties, guard rails, and fastenings. One railway makes provision, in all of its bridges, for a ballast floor, which is assumed to weigh 1,400 lbs. per ft. of track. When unit weights are specified, they are usually 4½ lbs. per ft. B. M. for timber and 100 lbs. per ft. of track for rails and fastenings.

LIVE LOAD.—Ten out of 28 specifications specify a concentrated load of from 45 to 62½ tons on four wheels. It will be noted that there is a great variety of engine loadings. The heaviest engine specified is 208½ tons, but the road using this also uses an engine weighing only 139 tons. The heavier engine is used for bridges on the mountain divisions. The lightest engine in the list is 131 tons, and in this case bridges are calculated for a succession of locomotives; that is, no uniform load is considered. The average weight of the 24 engines specified is 160 tons.

One specification gives a loading of four axle loads followed and preceded by a uniform load; one a series of mogul engines only; and two a series of consolidated engines only. Seven specifications give tables of equivalent uniform loads or of moments and shears.

The heaviest uniform load used is 5,500 lbs. per foot, and the lightest 3,200 lbs., but this is an exception, the next lightest being 4,000 lbs. Ten use 5,000 lbs. per ft.; 2 use 4,800 lbs.; 3 use 4,500 lbs.; and 7 use 4,000 lbs.

The heaviest engine with a 4,000-lb. per ft. following load is 172½ tons. The lightest engine with a 5,000-lb. per ft. following load is 139 tons.

The minimum load per driver axle is 37,000 lbs. and the maximum 66,000 lbs. These are exceptional and the range may be given as from 40,000 to 55,000 lbs.

The load per tender axle ranges from 22,000 lbs. to 35,750 lbs. The tenders weigh from 32 to 40% of the engine proper; 12 out of 22 weigh about 37% of the engine.

WIND LOADS.—The force of the wind is generally taken at 30 lbs. per sq. ft. for the loaded, and 50 lbs. per sq. ft. for the unloaded structure. The load per lineal foot is often specified in place of the load per square foot. The train is assumed to be 10 ft. high, which at 30 lbs. per sq. ft. makes a live load of 300 lbs. per ft. This is sometimes increased to provide for vibratory stresses. The same horizontal loads are used for trestles; the load on the bents varies from 100 lbs. to 225 lbs. per vertical ft. Several specifications require the use of different loads for unloaded structure.

CENTRIFUGAL FORCE.—The centrifugal force specified corresponds to a speed of from about 41 miles to 62 miles per hour, and is generally decreased for curves sharper than 5°. Several specifications give the same load per foot for all lengths of spans. In 11 specifications, it is doubtful whether dead load or live load unit stresses are to be applied to centrifugal force stresses; in 7, dead load units are specified; and in 8, live load units are specified or else there is no difference in the two units.

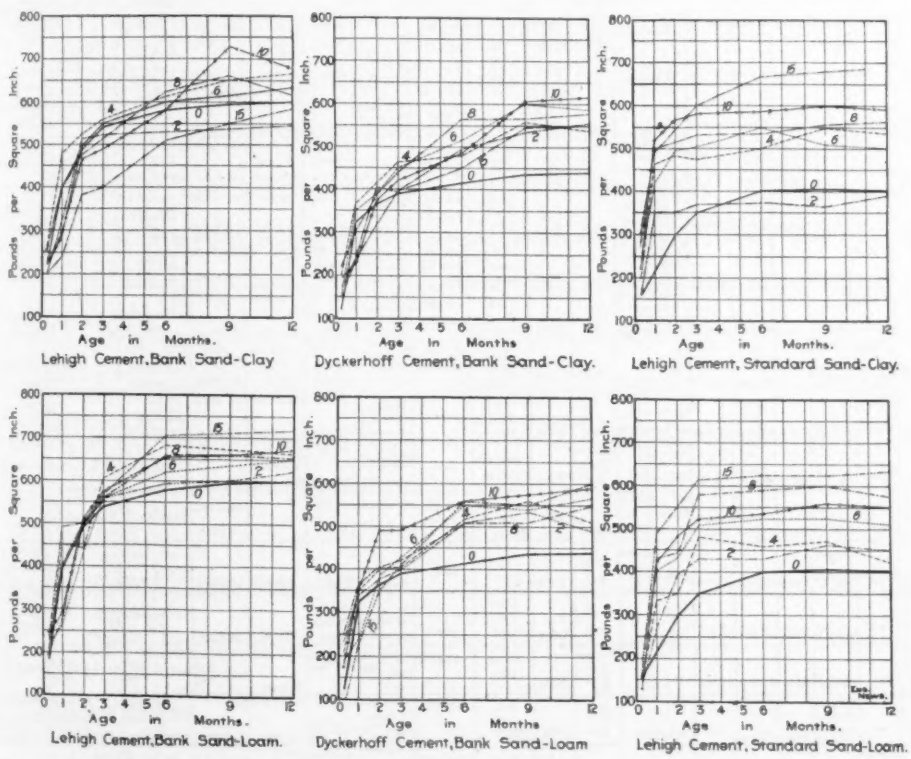


FIG. 2. DIAGRAM SHOWING EFFECT ON PORTLAND CEMENT MORTAR OF DIFFERENT ADMIXTURES OF CLAY AND LOAM.

Figures on Curves Denote Percentage of Loam or Clay.

IMPACT AND UNIT STRESSES.—The most characteristic and important classification of specifications can be made with reference to the impact and unit stresses allowed; these are closely related to each other. The most noteworthy fact is the abandonment of the "Launhardt Formula," and, to some extent, the adoption of a single unit stress applied to an equivalent static stress. The specification of a large system in which the Launhardt formula is used to a great extent is not included in the summary.

A multiplicity of unit stresses is still to be found in many specifications; a number of specifications give seven different column formulas. The more important units are given in the summary. For those specifications which give different column formulas for different end conditions, only the formula for "pin ends" is given in the summary. Of such there are twelve. In only six of the specifications is the "straight line" column formula found.

The following is a classification with reference to *impact* allowance:

(a) Ten specify no impact; five of these use a dead load unit equal to twice the live load unit; one uses a dead load unit equal to 1½ times the live load unit; one uses a dead load unit the same as the live load unit; and three use the Launhardt formula.

(b) One adds impact to excess load, using a dead load unit equal to twice the live load unit.

(c) One adds impact to part of web members, only using same unit for live and dead load stresses.

(d) One adds impact according to span, using the same unit for live and dead load stresses.

(e) Four add 0 to 30% to short spans, using a dead load unit about 1½ times the live load unit.

(f) One adds a variable impact, changing with the span, using a dead load unit 1.7 times the live load unit.

(g) Three make the impact depend upon the relation between the live and dead load stresses, using a single unit.

(h) One makes the impact depend upon the length of span, using the Launhardt formula.

(i) Six make the impact depend upon the loaded length, using a single unit.

The following is a classification with reference to unit stresses:

(a) Nine give a single limiting unit to be applied to the total stress, the live load stress having been increased to an equivalent static stress.

(b) Six give a dead load unit equal to twice the live load unit, which is equivalent to 100% impact. In this case the dead load unit is greater than the unit in case (a) in which the impact decreases as the span increases, and is 100% for zero span.

(c) Four give a dead load unit about 1½ times the live load unit, and add a decreasing amount of impact up to spans of from 75 ft. to 100 ft. The dead load unit is much smaller than in case (b), and the live load unit is about the same. This is equivalent to having 100% impact for long spans and a larger factor of safety for dead load. For the shortest spans the impact is 125 to 130%.

(d) One is like case (c) except that no impact whatever is added.

(e) One is like case (c), but with somewhat higher units and more extensive impact requirements.

(f) One gives a single unit about the same as the dead load unit in case (c), but adds more impact.

(g) One gives a single unit, such that the impact equivalent is in the neighborhood of 100%.

(h) One gives a single unit the same as the dead load unit of case (c).

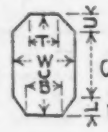
(i) Four use the Launhardt formula—one of these adding impact.

An example will show the difference in the amount of material required under the different specifications. Selecting a bottom chord member of a 134-ft. span, and assuming the dead load stress to be constant and to be 86,000 lbs. and the live load stress 184,000 lbs., the average of the sections required by the 28 specifications is 25.4 sq. ins. The minimum section is 11.4% below the average, and the maximum 18.6% above the average. Calculating a stringer for a 22-ft. panel, having an assumed effective depth of 34 ins., a constant dead load flange stress of 6,700 lbs. and a live load flange stress of 68,000 lbs., the average of the flange sections required by the 28 specifications is 9.2 sq. ins. The minimum section is 20% below, and the maximum 35% above the average. The total weight of the stringer will show a larger variation still, because some specifications permit and some prohibit, counting any part of the web as flange area. Ten specifications permit counting part of the web as flange area. One of

these allows it only in special cases; one allows 1/8 of area of web to be used when webs are heavy enough without stiffeners, excepting floor beams and stringers; three allow it when webs are variation below the average as above it. The difference in the amount of material required, under the different specifications, would seem to be excessive; but it is more important to know the smaller ones. The unit stresses for wind bracing are directly comparable and vary from 12,000 lbs. to 18,000 lbs. for practically the same wind loading in most cases.

SUMMARY OF REQUIREMENTS OF

Specification	Date	Lengths for which different kinds of bridges are used: I Beams	Plate Girders	Riveted Trusses	Pin Conn	Clearances (3): W	C	T	B	L	U	Loads.: Floor (1)	Cone Load	Engines	Unif. Load	Max. on Axle	Per axle of Tender	Impact	Wind Loads.: Dead	Live	Trestle	Centrifugal Force.	UNIT STRAINS. Tension. Main Members	Fl. Beam Stringers	Floor Beam Hangers &c.	Bracing	Compression: Soft Steel	Med. Steel
American Bridge Co.	1900	0 to 20'	20' to 100'	100' to 140	Over 140'	—	—	—	—	—	—	100 4½	None	Cooper's	Cooper's	Cooper's	Cooper's	S(300/(L+300))	30 50	300	30 50	.03WD up to 5°	15000 S.S. 17000 M.S.	15000 17000	15000 17000	15000 17000	15000/(1+L²/13500²)	17000/(1+L²/11000²)
No. 1.	1902	—	—	—	—	14	—	—	10	4	—	450	7'base 60T.	Cooper's E 50 177½T	5000	50000	32500	S(300/(L+300))	30	300	—	.03WD up to 5°	15000 S.S. 17000 M.S.	15000 17000	—	15000 17000	15000/(1+L²/13500²)	17000/(1+L²/11000²)
No. 2.	1901	10' to 20'	20' to 100'	100' to 120'	Over 120'	14	22	6	10½	4	4	100 4½	None	Cooper's E 50 177½T	5000	50000	32500	S(300/(L+300))	30 150	300	30 50	.02WD up to 5°	17000	17000	17000	17000	—	17000/(1+L²/11000²)
No. 3.	1902	—	Up to 105'	105' to 135'	Over 135'	14	21½	6	10	4	4	400 & 450	None	160T	5000	45000	30000	S(300/(L+300))	30 or 150	300	300k 150k 125 v.	.03WD up to 5°	15000 S.S. 17000 M.S	15000 17000	15000 17000	15000 17000	16000−70 L/F max. 16000 max.	18000−90 L/F 17000 max
No. 4	1898	—	—	—	—	15	21½	6	11	4	5	100 4½	None	Cooper's E 55 195½T	5500	55000	35750	S(300/(L+300))	30 50	300	300 30 50	.02WD up to 5°	15000 S.S. 17000 M.S	15000 17000	15000 17000	15000 17000	15000/(1+L²/13500²)	17000/(1+L²/11000²)
No. 5.	1901	—	—	—	—	14	22	6	10	4	5	60 4½	None	141T	4500	40000	28000	S(300/(L+300))	30	300	300 30	.025WD up to 5°	15000 Eyebars 16000	15000	15000	15000	—	17000/(1+L²/11000²)
No. 6	—	0 to 28'	Thro 28-80 Deck 28-100	Thro 80-125 Deck 100-125	Over 125'	15	22	6	11	4½	5	400	None	154T	4000	42000	30000	S/(S+S_D)	30	300	300k 300k 125 v. 560k 200v.	60 mi. per hr.	15000 Eyebars 16000	15000	15000	15000	—	15000/(1+L²/15000²)
Osborn Eng. Co.	1903	—	—	—	—	15	21½	8	11	5	6	100 4184	None	Cooper's	Cooper's	Cooper's	Cooper's	Hanger 125% S/(S+S_D)	150	Trusses 450 Pl Girds 330+30	300 30 50	WV² 32.2 r	15000 S.S. 17000 M.S	15000 17000	15000 17000	15000 17000	15000/(1+L²/18000²)	17000/(1+L²/18000²)
No. 7	1901	—	—	—	—	14	20	6	10	4	5	160 4½	None	151½T	5000	44000	30000	1−min./max. / 1+min./max.	30 50	300	300 30 50	Per lin. ft. 220D(1+V²/g)	S.S. 15000	S.S. I & B 14000 15000	S.S. 10000 Hip Verts 12000	S.S. 15000	15000/(1+L²/13500²)	—
Cooper	1901	0 to 20'	20' to 120'	75' to 150'	Over 150'	14	21	6	—	1	—	400 min. 100 4½	6 base 50T 60T	Cooper's	Cooper's	Cooper's	Cooper's	None.	150	450	600k 100v. 500k. 200v.	60−3D mi. per hr.	L.L. 10000 D.L. 20000	Soft tension 10000	Steel in 10% less 6000	L.L. 12000 Wind 18000	Soft Steel 15% less than med. 20000−90 L/F	Chords 10000−45 L/F Posts 8500−45 L/F 17000−90 L/F
No. 8.	1902	0 to 26'	26' to 106'	106 to 150'	Over 106'	14	23½	7	10	4	4½	With Ballast 1400 4½	None	208½ & 139T	4500 & 3200	66000 44000	33000 22000	None.	Min. 1000# per 30 50	300	800k 200v.	.03WD up to 5°	M.S Eyebars 18000 D.L.	Struct. Steel 8000	Struct. Steel 6000	Struct. Steel 15000	9000/(1+L²/20000²)	Struct. Steel
No. 9	1902	0 to 25'	25 to 100'	100' to 180'	Over 180'	14	21	7	10½	5	6	400	Tbase 60T	Cooper 142T	4500	40000	26000	None.	Min. 1200 and 2.00 30 50	300	—	WV²D 32.2g (g=32.16)	8000 L.L. 16000 D.L.	8000 16000	5330 10660	16000	8000/(1+L²/18000²)	L.L. 16000/(1+L²/18000²) D.L.
No. 10.	1901	0 to 34'	26' to 100'	80' to 120'	Over 100'	14	23	—	10	4	—	465	None	Cooper 159½T	4000	45000	29250	None.	Min. 1000# per 40 30	300	40 30 300 225 v.	165 D per ft.	S.S. Eyebars 18000 L.L. 16000 D.L.	S.S. 8000	S.S. Girders 7500 15000	S.S. 15000	8500/(1+L²/20000²)	10000/(1+L²/20000²)
No. 11.	1898	0 to 30'	30' to 90'	90' to 150'	Over 120'	14	23	6	10½	4	5	450	None	139T	5000	44000	22000	None.	None	Top 300 Bot. 450	—	50−2D mi. per hr. WV² 32.2 r	Eyebars 9500 L.L. 19000 D.L.	Medium Steel 10000	6000	16000	8500/(1+L²/20000²)	L.L. 17000/(1+L²/20000²) D.L.
No. 12.	1900	0 to 18'	18' to 125'	100' to 150'	Over 150'	14	22	8	10	4½	5½	400	For spans over 24' 5000 lbs per ft. + 100 on lb. excess up to 125' spans. 12000 lb. excess above 125' spans. Includes impact. 5000 50000						30 50 150	350	30 50 350	180D lbs. per ft.	9000 L.L. 18000 D.L.	For medium steel add 20% 9000 18000		18000	9000/(1+L²/18000²)	L.L. 18000/(1+L²/18000²) D.L & Wind.
No. 13.	1902	0 to 20'	20' to 100'	90 to 160'	Over 150'	14	22	7	10	4	5	400	Tbase 50T	154T	4800	44000	28000	30% Bms & Stringers 30% to 0% from 15' to 25' Spans.	125	300	125 300 100 v.	60 mi. per hr.	Eyebars 8500 L.L. 12500 D.L.	For 8000	medium steel 7000	12000	8000/(1+L²/18000²)	L.L. 12000/(1+L²/18000²) D.L.
No. 14.	1900	0 to 20'	20' to 100'	100 to 150	Over 150'	16	25	7	14 to 18	4	5	400	Tbase 60T	162½T	5000	50000	26400	30% Bms & Stringers 30 to 0% 25' to 100' Spans	125	300	125 300 100 v.	60 mi. per hr.	Eyebars 8500 L.L. 12000 D.L.	For med. steel add 8000	15% 7000	steel reamed add 12000	7500/(1+L²/18000²)	L.L. 11500/(1+L²/18000²) D.L.
No. 15	—	0 to 20'	20' to 90	90' to 160	Over 160'	14	22	7	10	4	5	400	Tbase 50T	138T.	4000	40000	24000	25% Bms & Stringers. 25 to 0% 20' to 70' Spans	125	300	125 300 100 v.	60 mi. per hr.	S.S. Eyebars 8000 L.L. 12000 D.L.	For M.S. - 8000	S. S. - 7000	S. reamed add - 12000	20% 7500/(1+L²/18000²)	S.S. L.L. 11500/(1+L²/18000²) D.L.
No. 16	1899	0 to 20'	20' to 95'	95' to 150'	150' up.	14	22	6	10	4	4	450	8' base 62½T	172½T	4000	50000	30000	None.	125	300	125 300 100 v.	60 mi. per hr.	Eyebars 9000 L.L. 13500 D.L.	For 6000	medium 5500	steel 12000	add 10% 7500/(1+L²/18000²)	L.L. 11500/(1+L²/18000²) D.L.
No. 17	1899	0 to 20'	20' to 100'	90' to 160'	150' up.	14	22	7	10	4	5	400	Tbase 60T	167T.	4500	50000	28000	30% Floor 25 to 0% 25' to 100' Span	150	300	150 300 100 v.	—	Eyebars 9000 L.L. 14000 D.L.	For 9000	med. steel 7500	add 12000	10% 8500/(1+L²/18000²)	L.L. 12500/(1+L²/18000²) D.L.
No. 18.	—	0 to 30'	30' to 100'	100' to 120'	Over 120	14½	22½	7	10	4	6-	4 400	—	146T	4000	42000	24000	18(1−L/400) to 23(1−L/400)	Min. 150 30 50	300	600 min. 125 v.	—	M.S. Eyebars 10500 L.L. 18000 D.L.	M.S. 12000	M.S. Eyebars 9000 D.L.	M.S. 14000	M.S. 10000−50 L/F L.L.	M.S. 16000−80 L/F D.L.
No. 19.	1898	—	—	—	—	15	22	8	10	4	4	100 4½	—	178T	5000	54000	28000 30000	Web members 25 to 65% to 25% 10'-200' spans	None.	300	30 50 300	60 ft. per sec.	11000 S.S. 12000 M.S	11000 12000	—	16500 18000	9000−35 L/F	10000−41 L/F
No. 20	1894 & 1900	—	—	—	—	14	20½	6	10	5	6	450	—	Mogul 147T	None	47000	30000	Web members 0 to 30%	30 50	300	—	—	Eyebars 9000	7000	4000	13500	7500/(1+L²/18000²)	Beams & Stringers 6000
No. 21.	1901	—	20' to 130'	60' up	Over 130'	C. to C. 20	21½	—	—	—	—	—	—	144½T	4000	42000	26000	None.	30 50	360	30 50 360	—	Eyebars 12000	9000 & 10000	7000	16000	10000/(1+L²/20000²)	Beams & Girders 8000 to 10000
No. 22.	1902	—	Up to 90'	90' to 150	150' up.	15	23	6	11	4	5	400	—	192½T	5000	55000	35000	None.	Min. 150 30 50	300	60 & 100	.045WD	Eyebars 8500(1+min/max)	8500(1+min/max)	Medium 6000	Steel 8500(1+min/max)	f<40 8500(1+min/max)	f>40 8000(1+min/max) −45 L/F
No. 23.	1899	—	Up to 80'	80' to 140	Over 140'	14	21	6	10	4	5	450	—	4 loads at 45 000 112T	5000	56000	—	None.	30 50	300	30 50 300	.03WD	For med. steel Eyebars 7500(1+min/max)	7500(1+min/max)	add 20% 6000	15000	6500(1+min/max)/(1+L²/18000²)	7600(1+min/max)/(1+L²/18000²)	Beams & Girders 7000(1+min/max)/(1+L²/18000²)
No. 24.	1896	—	—	—	—	15	20	6	12½ to 10	3½	6	450	8' base 45T	131T	None	37000	24000	25000 L	None	500	50 500	110(L+L²/5000)/f per ft.	X(1+DL/10k)	Eyebars —	M.S. —	10000	a/10000(1+L²/14000²)	
No. 25.	1899	—	—	—	—	15	21	7	11	4	5	450	7'base 50T	134T	4000	40000	22000	None.	30 150	300	650 125 v. 600 225 v.	—	M.S. Eyebars max/(1+L/D)	M.S. 9600	M.S. 6000	M.S. 18000	(7000−37 L/F)×max/(1+L/D)	(8500−45 L/F)×max/(1+L/D)
No. 26.	1901																											
No. 27.	1899																											
No. 28.	—																											
No. 29.	1900																											



1. From top of rail.
2. The smallest figures are weights per ft. B. M. The largest figures are weights per ft. of track of rails, ties, guard rails and fastenings. The intermediate figures are weights per ft. of track of rails and fastenings.

not spliced; one allows it for girders under 30 ft. long; four allow 1/8 of area of web to be used in all cases.

It is noticeable that there is not so wide a whether or not the excess is uniform throughout the structure.

Making allowance for impact, the largest unit for floor beam hangers is over 100% greater than

All specifications allow a higher unit stress for combinations of dead and live load stresses with wind, centrifugal force and traction stresses. About half specify the increased unit for com-

binations of dead, live, and wind load stresses: others for dead, live, wind and centrifugal force stresses; and a few for dead, live, wind and traction stresses.

units all applied to gross or to net section, and proper allowance were made for impact, there would not be a great difference in the requirements.

live and a dead load unit are given for main members, the rivet-bearing unit would be about right to correspond with the live load unit and the rivet shear would, on this basis, generally be high.

STANDARD RAILWAY BRIDGE SPECIFICATIONS.

UNIT STRAINS.

Specification	Date.	Combined D.L. L.L. wind & centrif. force	Shear: Webs	Shear: Rivets	Bearing: Rivets	Bearing: Masonry	Bearing: Rollers	Bearing: Pins	Bending: Pins.	Limits for compression members: Main Memb	Wind Bracing	Flange	Plate	Phos %	Material: Ultimate	Elastic Limit	Elong %	Bended Diam	Drifting to	Eyebars: Min.	Eyebars: Min Elongation	Reaming.	Planing.	Net Section.
American Steel Co	1900	Excess 26⅔% / 23½%	9000 S.S. / 10000 M.S.	11000	22000	400	4" min. 1200√d	S.S. 22000 M.S. 24000	22000 / 25000	100r	120r	16w	—	.08 / .05	48-55000 / 52-62000 / 60-70000	50% of ult.	26 / 25 / 22	0 / 0 / 1	1½d	47000 / 55000	10%	Med. Steel over ⅝" thick / Field Conns	Med. Steel over ⅝" thick	—
No. 1.	1902	26⅔% / 23½%	9000 S.S. / 10000 M.S.	11000	22000	—	4" min. 1200√d	S.S. 22000 M.S. 24000	—	100r	120r	12w	—	.06 / .04	48-55000 / 52-60000 / 60-68000	20000 / 28000 / 33000	28 / 25 / 24	0 / 0 / 1	—	—	—	M.S. except bracing, S.S. in tension, flanges & conn	Med. Steel Beams & Stringers	—
No. 2.	1901	23½%	10000	11000	22000	300	4" min. 1200√d	24000	25000	40d or 100r	120r	12w	6ot	.08 / .05	44-55000 / 55-65000	27000 / 30000	26 / 25	0 / 0	1½d	55000	10% to 12%	Matl. thicker than ⅝" Field holes exc. in bracing	Matl. thicker than ⅝" Beams & Stringers	Deduct holes coming within 1" of any plane.
No. 3.	1902	25%	9000 S.S. / 10000 M.S.	11000	22000	300	3½" min. 1200√d	24000	24000	100r	120r	12w	5ot / 32t	.06 / .04	48-55000 / 54-62000 / 60-68000	50% of ult	26 / 25 / 22	0 / 0 / 1	1½d	55000	In 15" 12%	Do.	Matl. thicker than ⅝"	Deduct holes whose centers are within 1½" of any plane.
No. 4.	1898	26⅔% / 23½%	9000 S.S. / 10000 M.S.	11000	22000	400	3" min. 1200√d	S.S. 22000 M.S. 24000	25000	100r	120r	12w	30t	.06 / .04	50-60000 / 60-68000	55% of ult	25 / 20	0 / 1	1½d	55-60000	In 10" 14%	All field holes except for bracing	None for spans less than 200'	—
No. 5.	1901	23½%	10000	11000	22000	400	2½ min. 1200√d	22000	25000	100r	120r	16w	32t	.08 / .04	47-57000 / 62-70000	50% of ult	26 / 22	0 / 1	1½d	58000	12½%	All matl. Field Holes except bracing	Matl. thicker than ⅝" Beams & Stringers	Deduct holes whose centers are 2½" or less from any section
No. 6.	—	25%	—	12000	25000	400	3" min. 500 d	25000	25000	120r	120r	15w	30t	.06 / .04	52-60000 / 60-68000	55% of ult	26 / 22	0 / 1	1½d	—	—	?	All matl. Beams & Stringers	Deduct holes whose centers are less than 2½" from any section
Osborn Eng. Co.	1903	25%	9000 S.S. / 10000 M.S.	10000	20000	—	4" min. 500 d	22000	25000	40d or 100r	120r	Strng 12w / 20w	—	.08 / .06	50-60000 / 52-62000 / 60-70000	30000 / 32000 / 35000	26 / 25 / 22	— / 0 / 1	—	55000	In 16" 12½%	Med. steel and soft steel in tension except bracing	—	Deduct holes coming within 1" of any section
No. 7.	1901	26⅔%	Net 13000	11000	26000	400	3" min. Med. St. 1200√d	22000	Med. St. 25000	100r	120r	12w	50t	.06 / .04	48-55000 / 52-62000 / 62-70000	28000 / 28000 / 33000	29 / 25 / 17	— / 0 / 1	1½d	S.S. 48000	In 10" 14%	Soft steel thicker than ⅝" Field holes except bracing	Beams & Stringers	—
Cooper	1901	30%	—	Floor 7200 / 9000	Floor 12000 / 15000	250	2⅞" min. 300 d	15000	18000	100r	120r	16w	30t	.06 / .04	50-58000 / 56-62000 / 60-68000	50% of ult	26 / 25 / 22	0 / 1 / 1½	1½d	56000	10%	Field holes except in bracing	Med. steel	Deduct all holes in diag. section unless there is 30% excess area
No. 8.	1902	50%	Gross 6000	7500	15000	300	4" min. 300 d	15000	18000	40d 100r	120r	16w	40t	.08 / .05	48-58000 / 55-65000 / 60-70000	50% / 55% / 55% of ult	26 / 25 / 22	0 / 0 / 1	—	55000	In 15" 12½%	Field Holes.	Beams and Stringers	Do.
No. 9	1902	25%	Net 6000 L.L. 12000 D.L.	Floor conns. 83⅓% 6000 L.L. 12000 D.L.	12000 L.L. 24000 D.L.	250 L.L. 500 D.L.	3" min. 400 d	12000 L.L. 24000 D.L.	14000 L.L. 28000 D.L.	100r	120r	12w	50t	.08 / .04	46-56000 / 56-64000	28000 / 33000	28 / 26	0 / 0	1½d	55000	In 20" 10%	All matl. except bracing	Matl. over ⅝" Beams & Stringers	Use line of least resistance
No. 10.	1901	50%	5000	7000	10000	250	4" min. 600√d	10000	18000	40d	—	—	32t	.08 / —	52-62000 / 60-68000	50% of ult	25 / 22	0 / 1	1¾d / 1¼d	47000 / 55000	10%	Med. Steel Field holes except bracing	—	—
No. 11.	1898	25%	6000	7500	15000	250	2⅞" min. 300 d	15000	22000	125r	—	20w	30t	— / .04	50-58000 / 60-68000	50% of ult.	26 / 22	0 / 2"	1½d	56000	In 10" 10%	Matl. over ⅝" Bms & Strings Field holes	Beams & Stringers	Deduct all holes in diag. section unless there is 30% excess area
No. 12	1900	25%	6750	6750	13500	300	4" min. 400 d	13500	16200	40d 120r	120r	12 & 16 / 20w & 12w	30t	.08 / .04	48-58000 / 54-62000 / 60-68000	30000 / 33000 / 36000	30 / 26 / 23	0 / 0 / 0	—	58000	14%	Soft st. over ⅝" Field holes except in brac.	S. Steel over ⅝" Beams & Stringers	Deduct holes coming within 1" of any plane.
No. 13	1902	25%	Net 6500	7500	13500	275	3½" min. 325 d	13500	17000	50d	—	20w	40t	.08 / .04	48-56000 / 54-62000 / 62-70000	50% of ult	28 / 24 / 22	— / — / 1	—	58000	In 10" 12%	M.S. & S.S. in tension, girder flanges, end connections and web of main members	Med. steel. Beams & Stringers	—
No. 14	1900	33⅓%	Net 6000	7500	12000	250	3½" min. 300 d	12000	15000	50d	—	12w	40t	—	—	—	—	—	—	—	—	Med. steel.	—	—
No. 15	—	33⅓%	Net 6000	7500	12000	250	3½" min. 300 d	12000	15000	50d	—	20w	40t	.08 / .04	48-56000 / 54-62000 / 62-70000	50% of ult	28 / 26 / 22	0 / 0 / 1	—	58000	In 10" 12%	Med. steel. Floor conns.	Med. steel. Beams & Stringers	—
No. 16	1899	25%	Net 4500	Floor 6000 Trusses 7500	Floor 12000 Trusses 15000	250	4" min. 250 d	15000 L.L. 22500 D.L.	15000 L.L. 22500 D.L.	50d	—	20w	—	.06 / .04	50-60000 / 60-68000	50% of ult	25 / 22	0 / 3t	1½d	56000	In 15" 12%	Med. steel. Soft steel > ½" Floor.	All matl.	—
No. 17	1899	25%	Net 6000	7500	12000	250	3½" min. 300 d	12000	15000	45d	—	20w	30t	.08 / .04	48-58000 / 54-62000 / 62-70000	50% of ult	28 / 26 / 22	0 / 0 / 1	—	58000	12%	Med. steel. Floor Conns.	Med. steel. Beams & Stringers.	—
No. 18.	—	25%	9000	7500	12000	275	2" min. 700√d	15000	20000	45d	—	—	30t	.08 Bes. .06	48-56000 / 52-62000 / 60-70000	55% of ult	28 / 26 / 22	0 / 0 / 1	—	—	—	—	—	—
No. 19.	1898	50%	8000 S.S. / 9000 M.S.	8000	14000	250	4" min. 530 d	14000 S.S. 16000 M.S.	20000	40d 100r	—	20w	32t	.04 .03 .05 .03	52-62000 / 52-62000 / 62-70000	32000 / 32000 / 35000	26 / 26 / 24	0 / 0 / 0	—	56-66000	In 10" 14%	All material	All matl.	Deduct holes whose centers are within 1½" of any section.
No. 20	1894 & 1900	—	Floor 4000 Girders 6000	6000	10000	200	2" min. 500√d	10000	15000	—	—	I's 30w	30t	.08 / .04	56-64000	60% of ult.	28	0	1½d	56000	15%	Drill tension members > ⅞" Field holes	—	—
No. 21.	1901	25%	Net 9000	7500	12000	(400) 250	3" min. 600√d	14000	20000	45d	—	30w	30t	.065	48-62000	33000	20	0 or 1	2d	58000	In 20" 10%	All material unless otherwise specified	All matl. Beams & Stringers	—
No. 22.	1902	30%	6000	7500	16000	300	6" min. 500√d	16000	18000	45d	—	—	—	—	60-68000	33000	20	0	—	55000	12%	Tens. members Floor system. Flgs. of girders	—	—
No. 23.	1899	Max. 15000	7000	7000	12000	200 & 175	500√d	12000	15000	—	—	—	—	—	52-60000 / 52-60000 / 60-70000	30000 / 30000 / 35000	25 / 25 / 22	0 / 0 / 0	2d	56000	10%	Med. steel. Beam & String Conns.	Med. steel.	—
No. 24.	1896	30%	a/10000 x 12000 = 1.2a	0.75a 1.31a	1.25a 1.56a	—	3" min. 470d	1.5a	1.5a	—	—	—	30t	.03 .03 .03	48-55000 / 54-62000 / 60-68000	— / — / 50%	28 / 26 / 23	0 / 0 / 0	—	56000	In 25" 12½%	—	—	—
No. 25.	1899	50%	6000	6000	12000	200	3" min. 600√d	15000	20000	45d 115r	—	20' or 20w	40t	.10	54-62000 / 60-68000	32000 / 34000	26 / 22	0 / 1	2d	56000	In 20" 13%	Med. steel. S. steel in tens. over ⅝" Thick and in compr.	—	Deduct holes coming within 1" of any section
No. 26.	1901													.07 .04	52-62000 / 60-68000	55% of ult	30 / 22	0 / 1	1.5d	56000	In 15" 15%	All except bracing etc.	Beams & Stringers	—
No. 27.	1899													.08 .04	44-56000 / 50-60000 / 60-70000	50% of ult.	26 / 26 / 22	0 / 0 / 1	—	55000	In 15" 10%	Med. steel. S. steel in tens. in flanges, end Conns. & web brace	Med. steel. Beams & Stringers	—
No. 28.	—													.08 .05	52-62000 / 60-70000	50% of ult.	25 / 22	0 / 1	—	55000	In 20" 10%	With members All matl.	Beams & Stringers	—
No. 29.	1900													.08 .04 .05	48-56000 / 52-62000 / 60-70000	55% of ult	28 / 26 / 22	0 / 0 / 1	1.3d	56000	In 12" 14 min. 15 ex.	Med. steel over ⅞" Thick	—	—

3. Clearances.
4. The larger figure is for acid steel and the smaller for basic.
5. The upper figures are for rivet steel, the lower for medium steel and the intermediate for soft steel.

Eight specifications give a unit for finding the net sections of plate girder webs; one for gross section; and the others do not specify but presumably their unit is for gross section. If the

About half of the specifications give a rivet unit in bearing about twice that in shear; the others generally give a smaller bearing unit compared with the shear unit. In those cases in which a

An allowed pressure per square inch of 250 lbs. on masonry, when no impact is considered, is equivalent to an allowed pressure of 400 lbs. per sq. in., when the impact is 75% of the live

load and the dead load is 20% of the total.

When the dead load is 30% of the total, the impact would have to be 85% to make the two units equivalent.

The unit bearing on rollers varies directly as their diameter in 14 specifications, and as the square root of the diameter in 14 cases. For a 4-in. diameter roller 300 d = 600 √d. For larger dameters the square root formula generally gives much smaller units. It is noticeable how the minimum diameter of roller allowed has increased in recent years.

The unit bearing on pins is, in nearly all cases, the same as for rivets, except that the former is often for medium steel, while the latter is for soft steel.

LIMITS OF COMPRESSION MEMBERS.—There is not much diversity in the maximum allowed length of compression members. For main members this is usually 100 times the least radius of gyration or from 40 to 50 times the least transverse dimension. For a post composed of two 10-in. × 20.0-lb. channels, 100 r = 36.6 ft. and 40 d = 33.3 ft. About one-half of the specifications allow an increase in the limit for wind struts. The allowable unsupported width of a compression flange varies from 12 times to 30 times its width, only a few exceeding 20 times the width. The unsupported width of plates in compression varies from 30 to 60 times their thickness.

MATERIAL.—Ten out of 31 specifications specify a single grade of steel (excepting rivet steel); five specify a soft-medium grade; nine prefer medium steel; nine prefer soft steel; and nine apparently use soft and medium steel without any preference. Twenty specify the minimum allowable elastic limit as a percentage of the ultimate strength, this percentage varying from 50 to 60; eleven specify a fixed minimum elastic limit; the purpose of this being, probably, to have a fixed basis for the working unit stresses.

The required percentage of elongation in 8 ins. is, for rivet steel (with a few exceptions), 26% or 28% for soft steel, 25% or 26%; and for medium steel (with a few exceptions), 22%. Soft and rivet steel are usually required to stand bending flat upon themselves, and medium steel to a curve whose diameter is equal to the thickness of the test piece. A required reduction of area is still given in a few specifications.

FULL-SIZE TESTS.—In full-size eye-bar tests the ultimate strength is generally allowed to fall 4,000 or 5,000 lbs. below the minimum required for specimen tests. When a soft-medium grade of steel is used, the eye-bars must be rolled from metal near the upper limit of ultimate strength so that a full-size test will not fall below the lower limit. It will be noted that there is considerable variation in the requirements of elongation in eye-bar tests.

REAMING.—Rivet holes are reamed for two purposes: to remove injured material, and, in the case of field holes, to secure a good connection. There are very few railway bridge specifications that do not require some sort of reaming. It is usual now to ream to an iron template all field holes in end connections of stringers and floor beams. Some specifications require the reaming of all field holes and the temporary assembling of the parts. Many require the reaming of all field holes except those in the bracing.

The specifications differ considerably with regard to general reaming. There are three that require none; two require all material to be reamed; ten require all medium steel to be reamed; two, all medium steel except bending; one, all medium steel thicker than 9-16-in.; three, all medium steel thicker than ⅝-in.; two, medium steel in tension except bracing; one, all soft-medium steel; one, all soft-medium steel except bracing; one, all soft-medium steel thicker than ⅝-in.; three, soft steel in tension, in flanges and in end connections; one, soft steel in tension, except bracing; one, soft steel in tension thicker than 9-16-in., and in compression thicker than ⅝-in.; one, soft steel thicker than ½-in.; and three, soft steel thicker than ⅝-in. Several allow the use of unreamed or reamed material at different unit stresses.

PLANING.—First-class work now requires the planing, to exact length, of floor beams and stringers. Planing of sheared edges is not so universally required as the reaming of rivet holes. It is usually confined to material thicker than ⅝-in., or to medium steel, and to important parts.

NET SECTION.—Formerly, specifications gave no rules whereby to determine the net section of a tension member in such cases where a diagonal section through the rivet holes might be weaker than a square one. Eleven out of 28, in the summary, give such a rule. The most rigid require-

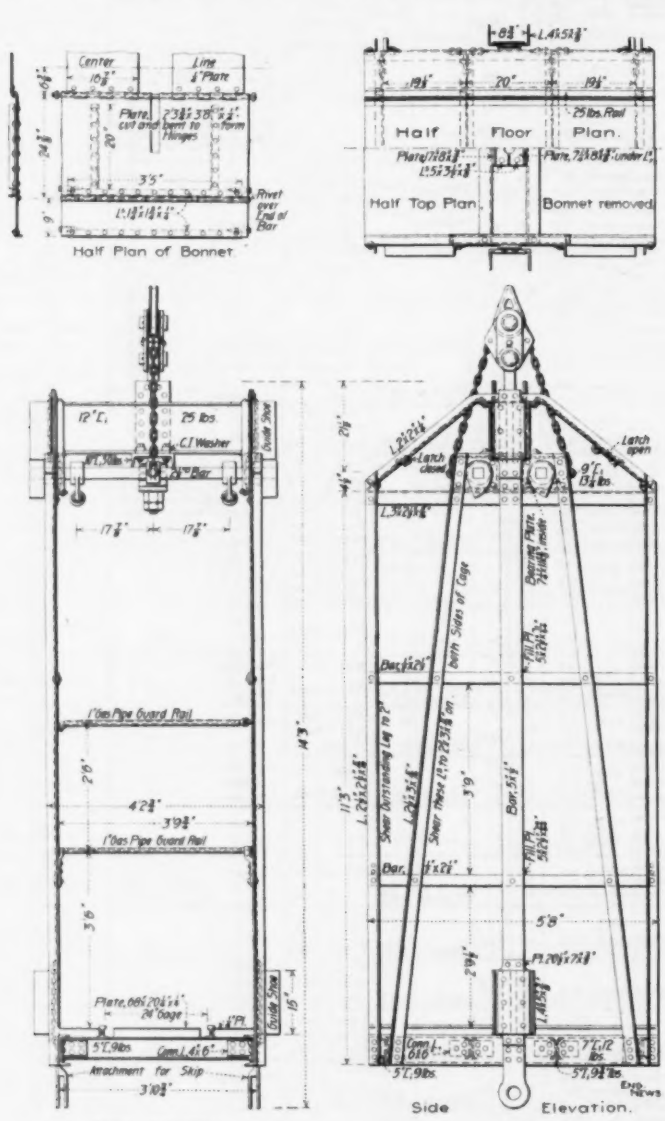


FIG. 1. CAGE FOR SIBLEY SHAFT (VERTICAL) AT ELY, MINN.; OLIVER IRON MINING CO.

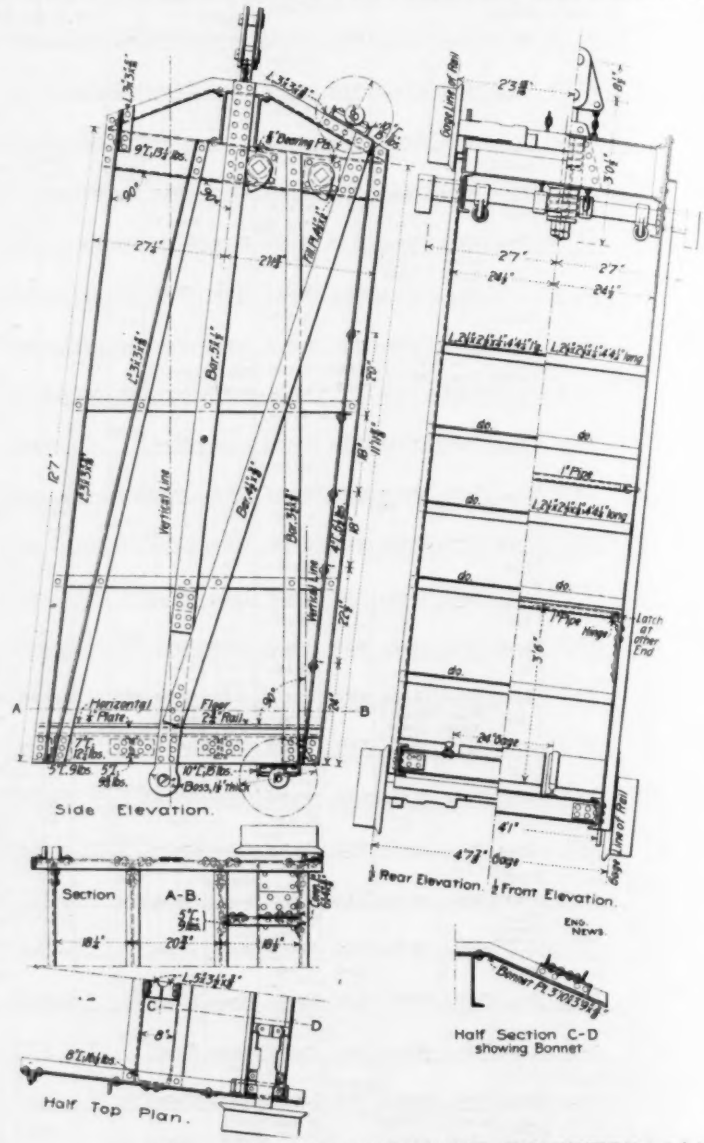


FIG. 2. CAGE FOR SAVOY SHAFT (INCLINATION 1 3-8 INS. PER FOOT).

Frank Drake, M. Am. Inst. Min. Engrs., Chief Engineer.

ment is the one that requires 30% more area in a diagonal section than in a square one, to make them of equal strength. It is safe to say that this rule is frequently violated. The other rules require (for ⅞-in. rivets), adjacent square sections through holes, to be from 2¾ ins. to 5 ins. apart if only those holes in a *square* cross-section are to be deducted from the gross section.

I have tried to give simply the facts, although it would be interesting to discuss the reasons for some of the requirements.

HOISTING PLANT AND STEEL SHAFT HOUSE FOR THE OLIVER IRON MINING CO., AT ELY, MINN.

During 1902 the Oliver Iron Mining Co., of Duluth, Minn., put down two new shafts near Ely, Minn., which are known as the Sibley and Savoy shafts. These shafts are some 1,500 ft. apart, but both are operated from a single hoisting plant, one shaft being about 500 ft. and the other 2,000 ft. from the hoisting plant. At each shaft is a steel shaft house, containing the head sheaves for the hoisting cables, and pockets for the storage of ore raised by the skips or cages.

From Mr. Frank Drake, M. Am. Inst. Min. Engs., Chief Engineer of the Oliver Iron Mining Co., we learn that the Sibley shaft is now 726 ft. deep, with a hoisting depth of 626 ft., and its hoisting compartments are 5 × 6 ft. The present tonnage raised is 425 tons in 24 hours. At the Savoy shaft the extreme depth is 719 ft.; hoisting depth, 619 ft.; and the hoisting compartments are 6 × 6 ft. The tonnage raised is 700 tons per 24 hours. The tonnage will be largely increased in the future, as will also the depth of hoisting, the ultimate depth being about 2,000 ft. The shaft timbering is of the ordinary pattern. The Sibley shaft is vertical, while the Savoy shaft is on a slight incline, 1⅜ ins. per foot.

CAGES AND SKIPS.

In both cases the skips are suspended underneath the cages, but the cages and skips for the two shafts differ in design, owing to the fact that one shaft is vertical and the other inclined.

CAGES.—The cages for the Sibley vertical shaft, Fig. 1, are 14 ft. 3 ins. high and 5 ft. 8 ins. × 4 ft. 2¼ ins. in plan. The framing is of steel angles and bars, with channels for the bottom framing. All the structural material is of soft open-hearth steel. The floor is of 2-in. plank, covered with ¼-in. steel plate, and between the planks are 25-lb. rails with a gage of 24 ins. for the mine cars. Two heavy bars transmit the pull to the skips underneath, and at the head is a 2½-in. drawbar of soft open-hearth steel. The two drawbar springs are of square steel, and have an outside diameter of 6½ ins., and a length of 7 ins. when free. The compression under 10,000 lbs. load is 1½ ins.

In the Savoy inclined shaft the cages run on four 18-in. flanged wheels on a track of 4 ft. 7⅛ ins. gage, as shown in Fig. 2. The framing is in general similar to that of the other cage, but with additional diagonal members, while the lower side of the frame is of 4-in. channels. The floor is horizontal. Attached to the safety catch are two extension springs of 7-16-in. round steel wire. They are to extend 7½ ins. under a load of 650 lbs. Similar springs are used on the other cage.

SKIPS.—The skip for the vertical Sibley shaft, Fig. 3, is 7 ft. high and carried between two upright angle iron frames, with a total height of 10 ft. 5¾ ins. The weight complete is 4,678 lbs. for a skip without lip, or 4,935 lbs. with a lip. The skip for the inclined Savoy shaft, Fig. 4, is 6 ft. 9 ins. high, and runs on four 18-in. wheels, like the cage. The construction is so clearly shown that detail description is unnecessary. Ordinarily, the skips are suspended beneath the cages, as already noted, being connected to the forked ends of the two heavy sidebars of the cage frame by means of 3-in. pins. If the skip is at any time required to be attached directly to the rope, a cross-frame with drawbar is fitted between the side frames of the skips, as shown by the dotted lines in Fig. 3.

HOISTING PLANT.

The hoisting plant is of the type known as a twin first-motion or direct-acting hoist; in other words, it consists of two first-motion hoists operated with one pair of engines. Each drum carries two ropes. Two of these ropes are used in the Sibley shaft, the other two in the Savoy shaft. The ore from the tram cars underground is not dumped directly into the skips, but dumped into large storage pockets. If the storage pockets were not used it would be impracticable to use one first-motion hoist for two shafts, as too much time would be lost in the two mines or shafts waiting for each other. When the skips are filled from the storage pockets the hoisting can be done with one hoist from two different mines, as in this case, without delay or waiting for the hoist at either shaft. It is the intention at this plant to hoist with only one drum at a time.

The hoisting plant is a good example of modern machinery of this class, and consists of a Corliss engine of 2,000 HP., with two drums on the same engine shaft. The drums are handled independently, and each operates the two compartments of one mine shaft. The engine was intended to be run condensing, but this plan has been changed, and no condenser is used. Ordinarily, the engines works with 125 lbs. of steam, but if necessary for any reason the pressure is raised to 150 lbs. The hoisting capacity of each drum is 28,500 lbs., distributed as follows: ore, 14,000 lbs.; rope, 6,000 lbs.; cage, 3,500 lbs.; skip, 5,000 lbs. The unbalanced load is 21,000 lbs. The hoisting speed is 2,000 ft. per minute. This plant was built by the Sullivan Machinery Co., of Chicago, and we are indebted to the builders for photographs, blueprints and other information. Fig. 5 is a view of the plant erected, and Fig. 6 shows the arrangement of the various parts.

The engine has cylinders 28 × 60 ins., 36 ft. apart, with connecting rods 12 ft. 6 ins. in length, driving a 14-in. main shaft supported by three bearings, 14 × 28 ins. The crank arms are of cast steel, set at 90°, and carry crankpins 8 × 8 ins. The engine has heavy girder frames, with the guides bored out to 30 ins. diameter to fit the segmental wearing surfaces of the crosshead shoes, which are 15 ins. wide and 30 ins. long. The cylinders are of semi-steel, steam jacketed on the barrels and ends and fitted with relief valves. Each cylinder is also fitted with a by-pass, which connects the ends of the cylinder and allows the piston to move freely when lowering the cage. The 5¼-in. piston-rods carry pistons of the bull-ring type, with anti-friction rings of babbit metal hammered into grooves in the face of the piston. The brake, reversing and clutch cylinders are all steam jacketed. The so-called "semi-steel" is

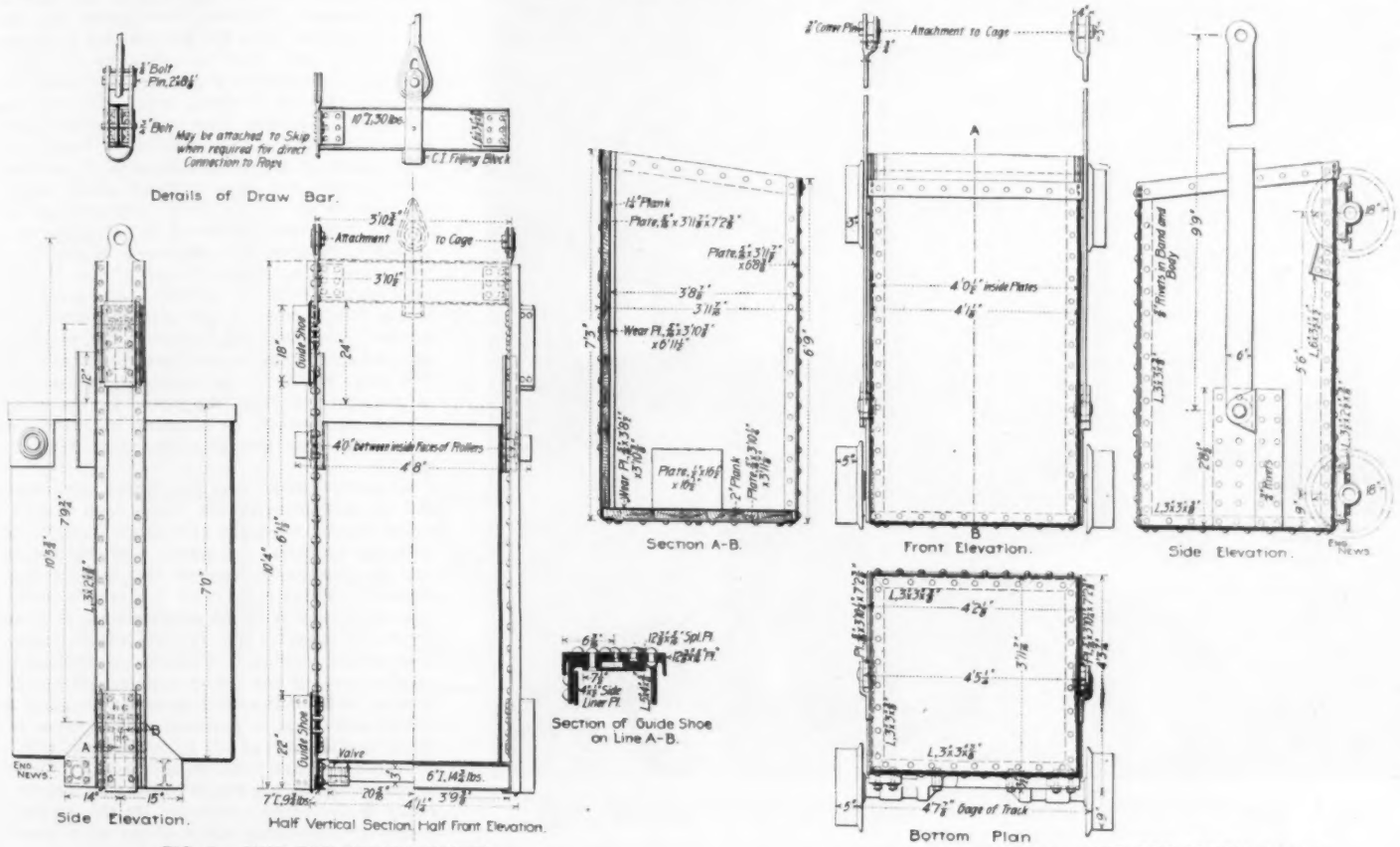


FIG. 3. SKIP FOR SIBLEY SHAFT.

FIG. 4. SKIP FOR SAVOY SHAFT.

used for cylinders, crossheads, and several other parts.

The ports and passages are all so proportioned that when working with steam of 150 lbs. pressure the velocity of the steam will not exceed 6,000 ft. per minute for admission or 4,000 ft. for exhaust. The valve motion is of the Corliss type, with long-stroke attachment, so as to give a late cut-off in starting. The cut-off is under control of the governor. The four valves are operated from a wrist plate. No eccentrics are used, but the valve motion is operated by an independent shaft driven from the engine shaft by a train of gears. At each end of this valve shaft is a small crank; from this a rod extends to the wrist plate from which the four valves are operated. Upon the shaft, at one end, is keyed a spiral resembling the coarse thread on a screw. Over this is fitted a cast iron shell or sleeve, the inside of which is threaded to fit the spiral. The sleeve, in fact, acts as a nut, and is moved to and fro (longitudinally with the shaft) by a steam cylinder. In moving, it causes the inner spiral and the shaft to revolve sufficiently to reverse the valve motion.

The engine speed is controlled by a quick-acting governor of the centrifugal type, the one governor controlling both cylinders. In connection with it there is a hand adjustment, so that speed can be regulated by increasing or decreasing the tension of a spring. A dial indicates the speed at which the engine will run under a given tension of the spring. The speed of the governor can be varied 5% or 6% in this way. The main throttle valves are of the double-beat pattern, and are closed automatically as the cages approach the end of their travel, a small auxiliary throttle valve being provided to control the engine during the completion of the travel, as described more fully below. All operations are controlled by levers and hand wheels grouped upon an elevated platform in front of the drums.

DRUMS.—The two drums are each 9 ft. long and 10 ft. diameter, having the shell carried by three spiders on the 14-in. main shaft, and being thrown in or out of action by means of a band friction clutch within the drum. The friction wheel is keyed to the shaft, and the band is carried by levers on the middle spider. Each drum is grooved for 1⅝-in. wire cable, and will carry 2,000 ft. of cable besides nine "dead" coils. Within the drum are two auxiliary reels (one at each end), each carrying 150 ft. of cable, so that the cable can be hauled in as it stretches or paid out if the shaft is carried down deeper. These are operated by hand-wheels and spur gear, and locked by clamps. On each end of each drum are two heavy band brakes, operated by a steam cylinder. In case the steam pressure should fall below a minimum of 100 lbs., due to leakage of steam pipes or other causes, an automatic pressure valve will be opened, which will admit compressed air at 60 lbs. pressure from a reservoir into the brake cylinders, and automatically apply and hold the brake. This valve, Fig. 7, consists of a hollow trunk piston or plunger working in a cylinder and having at each end a projecting stem, the ends of which close a port in one or other end of the cylinder head. The brake may also be applied by a hand wheel on the engineman's platform.

The hoisting drums are driven by steam-actuated band friction clutches, and, as already noted, the clutch is located inside of and at the center of the drum, and not at the end of the drum, as is usually the practice. The first reason for locating these at the center of the drum shells was to make the distance between the center lines of the cylinders as short as possible. The distance in this case is 36 ft., but if the clutches had been located at the ends of the drums, the distance c. to c. of cylinders would have been 40 ft. 6 ins. The second reason is to avoid the excessive torsional strain to which the drum shells would be subjected if the power required to start the load from the bottom were transmitted through the entire length of the drum. When only one rope is used on each drum, the rope is fastened to the end of the drum nearest the clutch, and the heaviest part of the work is done with the end of the drum nearest the clutch; the load is then getting lighter as the rope is wound on the drum when winding from the clutch-driven end of the drum. In the case of the Savoy and Sibley shafts, where two ropes are used on each drum, one of the loads would be started from the bottom with the end of the drum farthest away from the clutch.

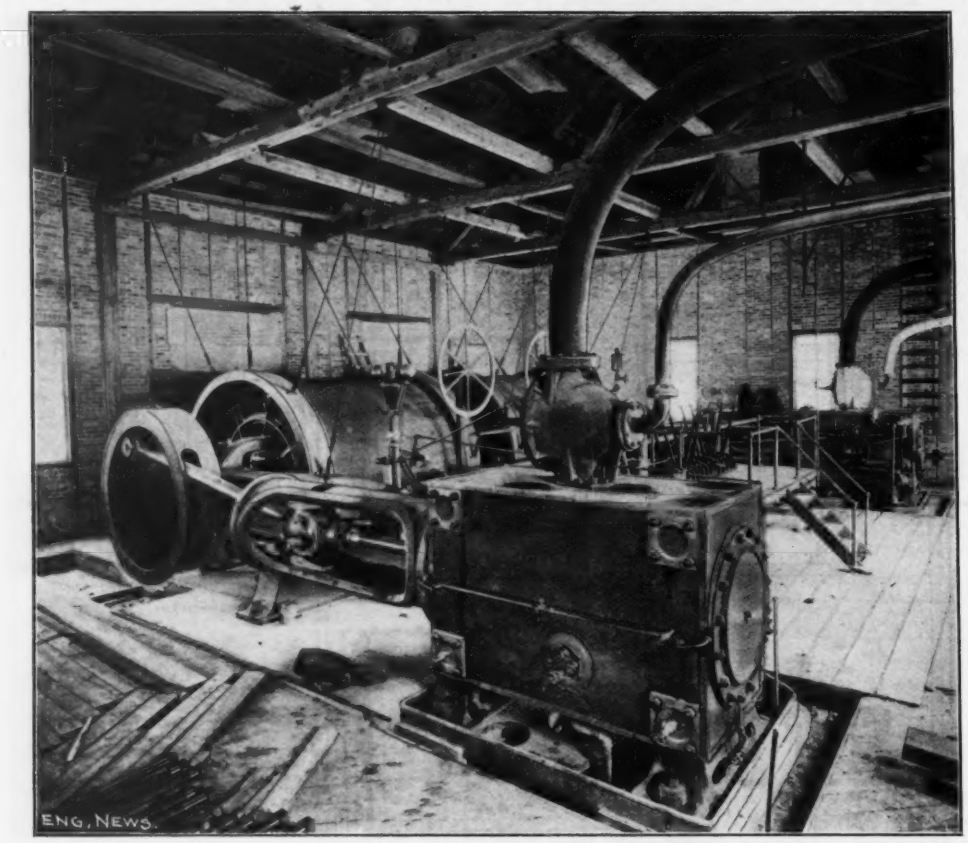


FIG. 5. VIEW OF HOISTING PLANT FOR THE SIBLEY AND SAVOY MINES, ELY, MINN.

BRAKES.—Each drum is provided with two brakes of the continuous band type. Each brake band is 16 ins. wide and made of ½-in. steel. The basswood blocks are bolted to the brake rings, and not to the brake bands, as is usually the practice. The reason for this is to avoid the heating of the brake flange, which has proved an annoying in many hoisting engines. While the heating of the brake of a first-motion hoist is not so serious a matter as where a geared second-motion is used, where the lowering is done under the friction of the brake, it was nevertheless decided to eliminate all trouble caused by the heating of the brake bands. The heat of the steel brake band is soon absorbed by the atmosphere, whereas the heat of the cast-iron brake rings is retained by the brake blocks, when the blocks are bolted to the brake band.

The two brake bands on each drum are operated with one steam-jacketed steam cylinder. An equalizing device is provided for the purpose of equalizing the tension of the two brake bands. If in adjusting the two brake bands for wear one becomes a little shorter or longer than the other, the equalizing device will compensate for this inequality, and the two brakes grip the drum with equal tension. Without this device, one brake band might be doing the greater part of the work, even after they were adjusted, as it would be practically impossible to adjust these bands so accurately that all of them would grip with equal tension. All hinges, lugs and levers on the band friction clutches and brakes are of forged steel.

For each of the brake cylinders is provided a valve which will automatically admit steam or compressed air to the brake cylinders, as above noted. Whichever pressure is the higher is admitted to the cylinders, whether it be steam or air. This valve is so designed that in case the steam pipe leading from the boilers to the plant should break, it will shut off the passage leading to the broken connection, and admit to the cylinder the air pressure from the compressor storage tank. The valve will act in the same way in case the air is disconnected from the brake by the stopping of the compressor, or breaking of the air pipe. Each brake can also be operated by hand, if required.

Located tandem with the brake cylinders are the oil cushion cylinders, which tend to give the brake pistons a smooth and steady movement. In ordinary practice, a positive valve is located in the oil passage connecting the ends of the oil cylinder. When a valve of this kind is used, the rate of movement of the brake pistons is constant or not graduated. If it is necessary to apply the brakes very suddenly, it cannot be accomplished, as the travel of the piston is prevented by the oil flowing through the fixed opening. To avoid this, the present plant is provided with a valve which controls the flow of oil in connection with the differential steam valve on the brake. This valve is connected to the steam valve that admits the steam to the brake cylinders. By this method the necessary cushioning effect of the oil is obtained, while at the same time the rapid movement of the piston is also permitted when it is necessary to apply the brakes suddenly. A differential valve movement is provided for admitting the steam to the brake pistons, and the travel of the brake piston is simultaneous with the movement of the lever located on the handling platform. In other words, when the operator moves the lever, the piston will also move. When the hand lever is stopped in any position the steam piston will also come to a standstill. Without the differential valve movement the piston would travel the entire length of its stroke when the steam admission valve is open, and the brake piston could not be brought to a standstill in any intermediate position between the two extremes of its travel and held in that position. The oil cylinder is fitted with an adjustable valve to regulate the flow of the fluid and so regulate the travel of the piston.

AUTOMATIC THROTTLE-CLOSING MECHANISM.—To prevent accidents from overwinding, a mechanism has been introduced to automatically close the steam throttles at any given point, the point of closing being determined according to the load and steam pressure. On the hoist in question the main throttles are closed automatically

when the skips are 360 ft. below the landing. The momentum of the machinery (cages, skips and rope) will complete the lift of 360 ft. The engines, of course, will slow up gradually, so that when the cages reach the dump or the landing, the speed is so reduced that the automatic brake will bring the moving parts to a standstill in case the operator forgets to apply the steam brake at the proper time. An automatic brake is useless without the automatic throttle, for if full speed of the engine is maintained up to the landing place or dump no automatic brake can bring the engine to a standstill in a sufficiently short space of time to prevent an accident. The inertia of the moving parts must be reduced beforehand by shutting off the steam. The automatic mechanism is so arranged that after the main throttle valves are closed the engineman cannot reopen them until the engine is reversed for the return trip. A blocking mechanism in connection with the reversing engine is the means employed for keeping the valves closed. When the engine is reversed, this blocking mechanism is withdrawn, and the main throttles can be opened.

If it were possible to keep the steam pressure and the loads constant, the automatic closing device could be so adjusted that the landing or dump could be reached without providing any auxiliary source for admitting steam to the engine cylinders, after the main throttles are closed. But as the pressure and loads cannot be kept constant on a hoisting engine, a small by-pass throttle is provided, operated with a foot lever. This throttle is on a 2½-in. pipe. The foot throttle will be so adjusted that enough steam will be admitted through it to complete the lift when the engineman sees that the hoist will come to a standstill shortly before the cage reaches the landing. The amount of steam admitted through this small pipe and throttle is such that the engine will run at a very slow speed (7 to 10 revolutions), and the landing is reached at a speed sufficiently slow to be checked with the automatic brake, even if the engineman forgets to close the throttle.

This auxiliary or foot throttle is also used where very short movements of the skips or cages are necessary. With the high steam pressures that are coming into use, it is rather difficult to properly control the speed of the engines for short movements by admitting this high-pressure steam through the main throttles, especially where the drums used are of small diameter. The auxiliary or by-pass throttle allows the steam to flow into the cylinders gradually. This throttle is also used when starting the load. Instead of pulling the throttles wide open under the full boiler pressure, the by-pass throttle is open wide, and the slack of the hoisting ropes is taken up more gradually than with the full head of steam admitted through the large throttles.

AUTOMATIC BRAKE.—In case of overwinding, the steam is admitted automatically to the brake cylinder by means of a heavy lug bolted to the flange of the drum. The edges of the drum flanges are turned on an angle, usually referred to as a dove-tail, and this shape of the flange enables the lugs to be set and clamped at any point of the drum circumference. When the height limit is reached, a pointer that is a part of this lug takes hold of the steam valve connection to the brake cylinder, and turns full steam on it instantly. In connection with this, the description of the valve in the cushion cylinder for the brake already referred to as being connected up to the differential valve-gear, must be borne in mind. When the lug on the drum flange turns the steam on the brake cylinder the oil valve is also open wide and permits the steam piston to move instantly without being restricted by the oil or cataract cylinder, as it would be in case a positive valve were used.

Up to within a few years ago, when the hoisting speeds were lower than at present, a detachable weight was used for admitting the steam to the steam brake in case of overwinding. This weight, being suspended on a detachable hook, was detached and allowed to drop on a lever, that in turn was connected with the steam valve of the brake cylinder. But although the space of time required for this weight to drop 18 ins. or 2 ft. was very short, it was still too long for safety, as the hoisting drum in most cases would make a half turn or more during the same space of time that the weight would drop and the brake go into action. The weight mechanism being so slow, higher engine speeds made it necessary to devise something that would act instantaneously. When the steam valve takes its movement from a positive lug on the drum flange, as on this engine, the full steam pressure will be admitted to the brake piston at the same instant that the pointer on the drum flange comes in contact with the connection for the steam valve.

The reversing gear, brakes and drum clutches are all operated by steam cylinders, which have oil cataracts attached, in order to prevent shocks. Indicators with pointers and dials show the positions of the cage at all times. These are driven from the hubs of the drums by cut spur and bevel gearing, no worm gears or sprocket chains being used by this company on its large hoisting plants. To indicate small movements of the cage when it is near the dump or landing, the flanges of the drums are turned and beveled for a width of 2 ins. and graduated, a fixed pointer showing the movement of the graduation marks.

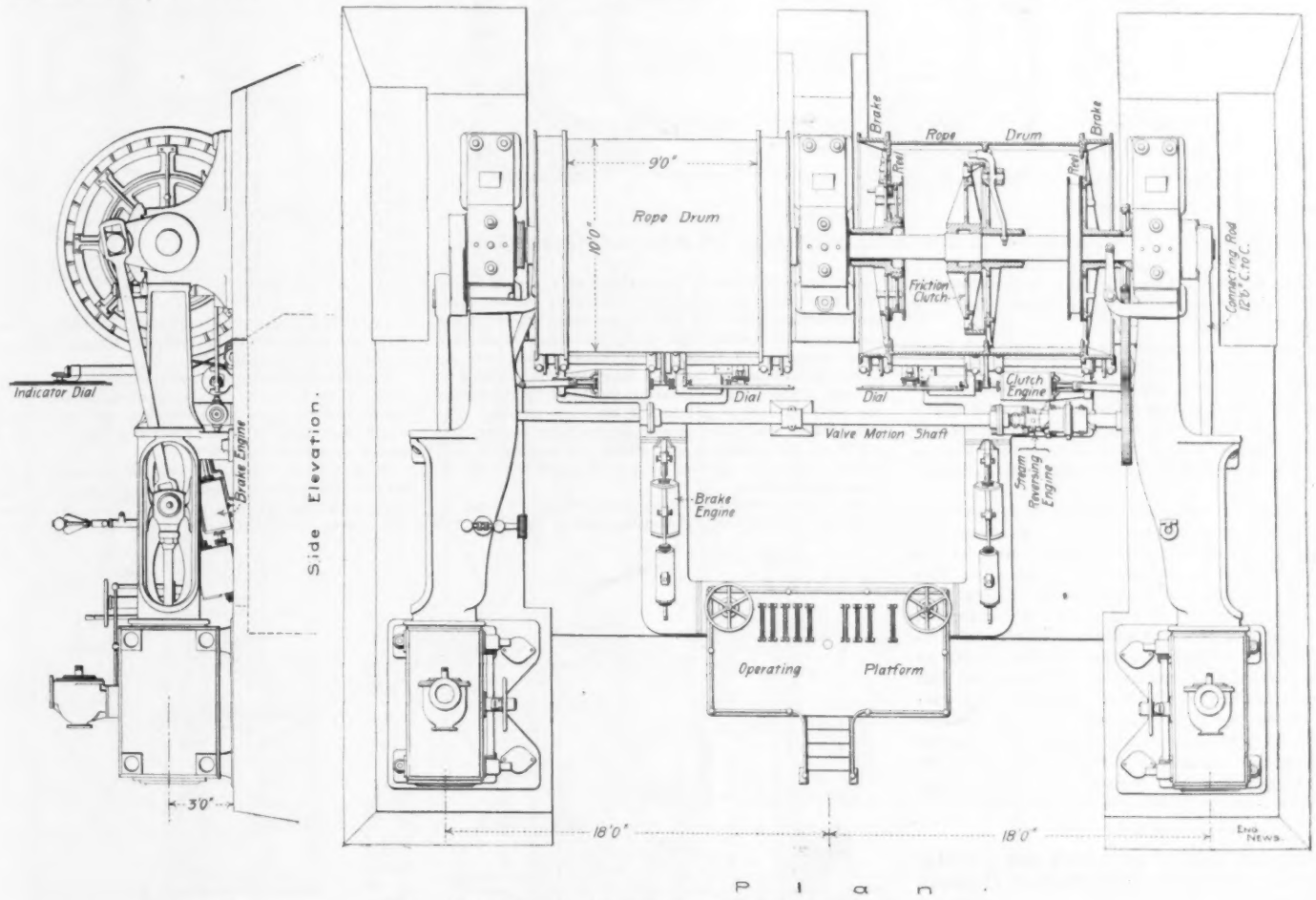


FIG. 6. HOISTING PLANT FOR THE SIBLEY AND SAVOY SHAFTS.
Sullivan Machinery Co., Chicago, Builders.

STEEL SHAFT HOUSE.

The use of steel shaft houses for mines is becoming very general in certain districts, and the Savoy and Sibley shafts of the Oliver Iron Mining Co., already mentioned, are thus equipped. The shaft house at the Sibley mine is shown in Figs. 8, 9 and 10. This structure was built by the Minneapolis shops of the American Bridge Co. The shaft house is 30 ft. wide on the face and 75 ft. deep at the ground level, while the total height from the collar of the shaft is 158 ft. The weight of structural steel used was about 265 tons.

The main framing consists of a series of columns composed of pairs of steel channels, with horizontal lines of steel channels framed between them. As it was not advisable to build column

foundations close to the shaft, the front columns are supported on a heavy box girder, the center line of which is 5 ft. 5 ins. from the center of the shaft. At the rear of the house are two heavy inclined columns, acting as braces to resist the pull of the hoisting ropes, which pass over the two 12-ft. grooved sheaves near the top of the structure. At a height of 33 ft. above the shaft there is a projection on the shaft house to enclose the guides and cages, this projection being supported by cantilever girders with latticed webs. At the level of the first floor also there is a line of 36-in. plate girders and lattice girders between the outer columns, instead of the 15-in. channels between the inner columns which are shown in the section, Fig. 9.

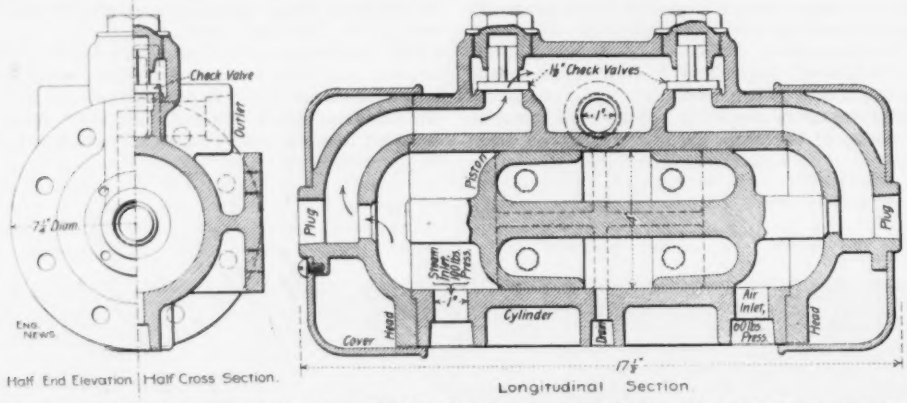


FIG. 7. AUTOMATIC PRESSURE VALVE CONTROLLING BRAKES ON MINE HOISTING ENGINE.

The fine ore and lump ore are dumped from the cages through separate hoppers into bins or pockets, from which the ore is discharged as required into railway cars standing on tracks which run through the shaft house. The hoppers are of 5-16-in. steel plate, while the pockets have a plank lining attached to the structural framework.

Steel channels are principally used for the columns and girders, supplemented by plate and lattice girders at certain points, particularly at the ore pockets, and for supporting the sheaves. The diagonal members are principally single and double angles. The sheathing is of corrugated steel. All field connections are riveted. In construction, all columns having 11-16-in. holes at splices were bolted together at the shops and had the holes reamed to 13-16-in. diameter. All surfaces which would be inaccessible after erection were given two coats of iron ore paint. When the structure was completed it was given two coats of similar paint, with the exception of the lining, woodwork and the interior of the ore hopper.

THE REQUIRED AMOUNT OF WATER FOR A PUBLIC SUPPLY, ILLUSTRATED BY EXPERIENCE AT PROVIDENCE, R. I.*

By J. Herbert Shedd,† M. Am. Soc. C. E.

The conditions for limiting a water supply to useful purposes are as follows:

(1) A tight distribution and service system.

(2) A proper system of water rates, inducing the water takers to desire rather than oppose the use of meters.

(3) The measurement of all water drawn by takers and payment in proportion to volume. (As an incident to this, a determination of the supply required for various uses is desirable.)

(4) Watchfulness on the part of those in charge of the works to detect and remedy any abnormal condition in the supply.

On existing works, but little can be done to improve the tightness of present distribution and service systems, but renewals and extensions should be made in such a way as to secure reasonably tight work. This requires proper specifications, and rigid inspection, both at the foundry and on the pipe-laying. The shapes and dimensions of bells and spigots are important. The bells are usually made too deep. The practice at Providence might well be followed, where bells of 6-in. pipes are 2 ins. deep, and those of 36-in. pipe are 4 ins. deep. In Providence, tightness of services is obtained by specifying the best of material, and by having the services put in by water-works employees.

The system of fixture rates for water should be based on the opportunity of each taker to waste water; and the size of the service pipe should be fixed by the amount of useful water required. A diagram showing the loss of head resulting from various deliveries through taps of different sizes and service pipes of various lengths has proved of great value in Providence.

The measurement of the quantity of water delivered is the only just basis of a charge for water. The fire protection afforded by a water supply is a proper cause for a public tax, which should generally yield one-half the revenue of a water-works system.

Providence is taken as an example of a city in which the water supply is limited to a reasonable amount without dissatisfaction on the part of the water takers. Since more water is wasted than used, the means of wasting water governs the rental where water is not sold by meter; the schedule is therefore based upon the number of fixtures. This naturally makes it an object for those having many fixtures to put in and maintain meters. The water takers have thus become advocates of meters, and nearly all the meters in use, which now amount to 85% of the number of services, have been applied at the request of the takers.

The rates for metered water were originally fixed at 3 cts. per 100 gallons. Assuming that at that rate $10 per year would pay for all the water that would be legitimately used by an ordinary family, the minimum charge was fixed at this sum, so that there should be no temptation to restrict the proper use of water. Experience showed that 15 years after the works were built one-half of the families supplied were paying the minimum rate. this entitled them to 91.3 gallons per day per family. For many years a large number of families supplied did not draw more than $5 worth of water per year.

In 1888 an analysis was made of the accounts of metered water takers. Of those paying the minimum rate, the accounts of 2,553 families showed that:

Families	Per year;	Per day.
167	drew less than ....1,500 cu.ft., or	31 galls.
237	drew bet. 1,500 and 2,000 cu.ft., or	31 to 41 galls.
361	" " 2,000 " 2,500 " "	41 " 51 "
445	" " 2,500 " 3,000 " "	51 " 61 "
446	" " 3,000 " 3,500 " "	61 " 72 "
462	" " 3,500 " 4,000 " "	72 " 82 "
435	" " 4,000 " 4,457 " "	82 " 91 "

If the average family consists of five persons, families of a good class are thus shown to be using only from 6 to 18 gallons per head per day.

The analysis of accounts further showed the number of meters passing different quantities of water, as shown by the charges, as follows:

Charges.	No. of accounts.	Charges.	No. of accounts.
Minimum.....2,681		$100 to $300.....	161
$10 to $15.....1,542		300 " 500.....	35
15 " 20..... 887		500 " 1,000.....	20
20 " 30..... 861		Over $1,000.....	13
30 " 40..... 393			
40 " 50..... 176		Total.....	7,074
50 " 100..... 294			

The following table shows the population, per capita consumption of water, and percentage of services metered, in Providence, from 1877 to 1902, inclusive:

Year.	Population.	Daily consumption per head (galls.).	Percentage of services metered.
1877.....	102,900	24.2	41.9
1878.....	104,800	25.8	43.3
1879.....	106,875	29.1	44.9
1880.....	109,400	32.4	46.6
1881.....	112,200	33.1	47.7
1882.....	115,100	31.9	
1883.....	118,000	35.1	52.4
1884.....	120,900	33.8	53.1
1885.....	123,800	38.2	55.3
1886.....	126,700	38.1	56.8
1887.....	129,700	38.1	58.1
1888.....	132,600	41.6	59.3
1889.....	135,700	42.6	60.6
1890.....	138,700	48.6	62.5
1891.....	141,800	51.3	63.4
1892.....	144,900	55.6	65.5
1893.....	148,000	63.3	69.4
1894.....	151,800	65.2	72.5
1895.....	156,400	56.9	74.6
1896.....	162,200	56.1	76.5
1897.....	168,200	51.3	78.4
1898.....	174,200	52.5	80.0
1899.....	180,000	52.9	81.5
1900.....	186,800	54.2	82.6
1901.....	193,000	55.6	83.6
1902.....	199,400	58.0	84.4

An equally low per capita consumption might be secured in nearly every city in the country without permanently annoying the inhabitants.

The effects of electrolysis are believed to account for the recent increase in the per capita consumption; but electrical conditions are being steadily improved, and it is hoped that waste of water from this cause can be kept within reasonable limits.

Three men set, repair, and read all the meters in Providence. The expense is paid by the takers, a fixed charge being made against each meter for the usual operations. The average annual cost per meter for repairs is about 11½ cts. Meters are owned by the consumers, but are furnished and set by the city.

In Providence, as in other places, there are some people who will tap in a supply back of the meter, and thus take water without having it metered. Eternal vigilance is necessary to detect and prevent this and other surreptitious use of water.

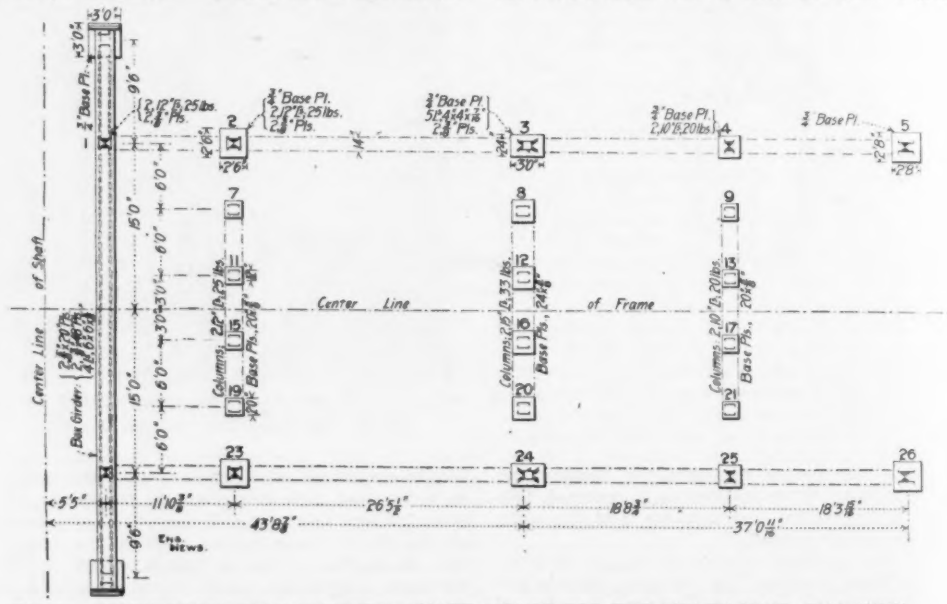


FIG. 8. FOUNDATION PLAN OF STEEL SHAFT HOUSE FOR THE SIBLEY MINE, ELY, MINN.

DISCUSSION.

Mr. Walter R. Richards, of New London, Conn., called attention to the fact that the per capita consumption will vary with the character of the city. Thus, a manufacturing city like Woonsocket would show a very much smaller use of water than a residence city like Newton, Mass., while they might be equally free from waste.

Mr. R. C. P. Coggeshall, of New Bedford, asked for information regarding the possibility of accounting for all the water pumped, and Mr. Robertson, of Fall River, gave a brief account of the attempts to do this there, and spoke

*Abstract of a paper and discussion before the New England Water-Works Association, Boston, Nov. 11. The paper and discussion in full will be printed in a future number of the "Journal of the New England Water-Works Association."

†Consulting Engineer, Providence, R. I.

particularly of the usually extravagant use of water in public buildings.

Mr. R. J. Thomas, of Lowell, said that after a recent fire, impure canal water from the fire pipes of the mills had found its way into the city mains past defective check valves, and had resulted in considerable sickness. The gates on the fire connections had been closed as soon as this was discovered, and the consumption of the city had thereupon been reduced by from 250,000 to 500,000 gallons per day.

Mr. E. C. Brooks, of Cambridge, said that in that city, with only 0% of the services metered, and those mostly manufacturing services, the sales of metered water amounted to 37.5 gallons per head per day.

In response to a question about slip of pumps, Mr. Shedd stated that if the pumps are well cared for he thought the slip ought not to exceed from 2 to 4%. Mr. Dexter Brackett, M. Am. Soc. C. E., of Boston, said that he had tested one pump where he found a slip of 50%, and he knew of other tests showing 40% slip. Some of the pumps of the Metropolitan Water-Works have been found to have from 3 to 13% slip. Mr. F. W. Dean, M. Am. Soc. M. E., of Boston, said that a test of the Morris engine at Lowell, which had been used a great many years, showed but 5% slip; while a recent test of a pumping engine in New York showed a slip of 36%.

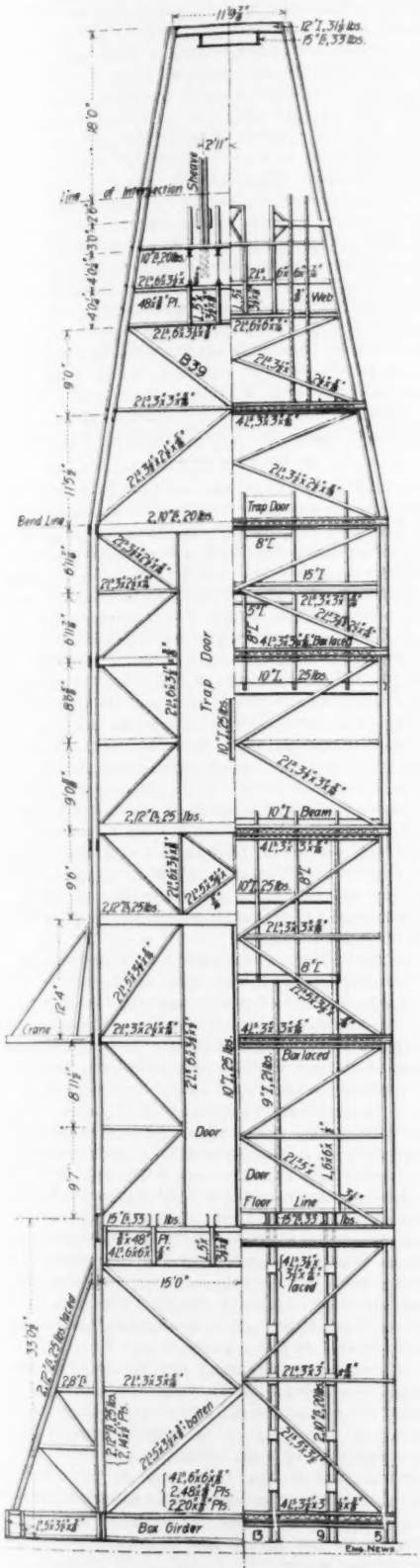


FIG. 10. FRONT AND REAR ELEVATIONS OF STEEL SHAFT HOUSE.

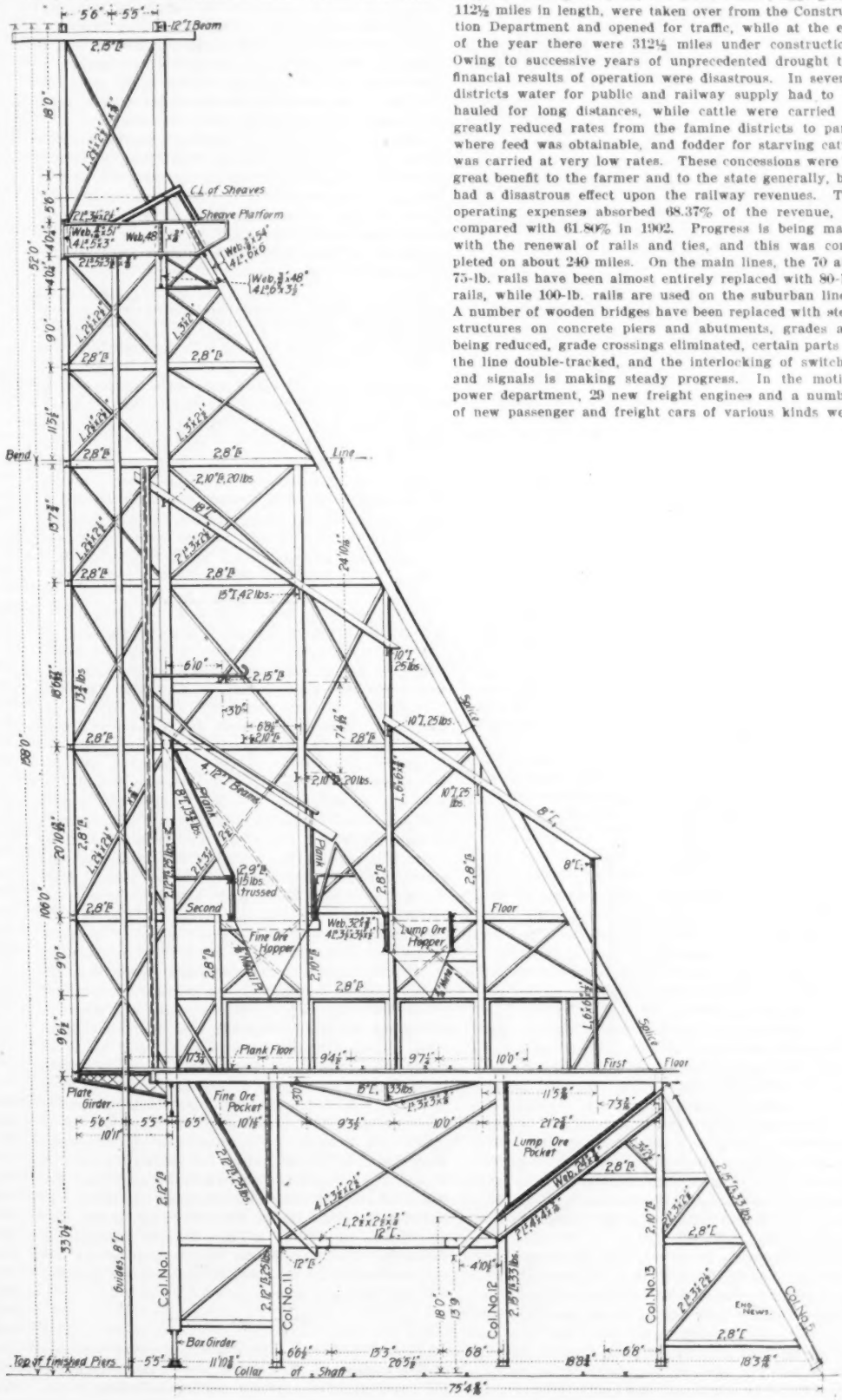


FIG. 9. SIDE ELEVATION OF STEEL SHAFT HOUSE.
American Bridge Co., Builders.

THE RAILWAYS OF NEW SOUTH WALES, Australia, are owned and operated by the government, through the medium of a Board of Railway Commissioners, and the report of this board for the year ending June 30, 1903, has recently been issued. The report covers not only the railways, but also the tramways or street railways of the city of Sydney. The length of line open for traffic was 3,138½ miles, with a capital cost of $208,274,885. During the year, two pioneer lines, aggregating 112½ miles in length, were taken over from the Construction Department and opened for traffic, while at the end of the year there were 312½ miles under construction. Owing to successive years of unprecedented drought the financial results of operation were disastrous. In several districts water for public and railway supply had to be hauled for long distances, while cattle were carried at greatly reduced rates from the famine districts to parts where feed was obtainable, and fodder for starving cattle was carried at very low rates. These concessions were of great benefit to the farmer and to the state generally, but had a disastrous effect upon the railway revenues. The operating expenses absorbed 68.37% of the revenue, as compared with 61.80% in 1902. Progress is being made with the renewal of rails and ties, and this was completed on about 240 miles. On the main lines, the 70 and 75-lb. rails have been almost entirely replaced with 80-lb. rails, while 100-lb. rails are used on the suburban lines. A number of wooden bridges have been replaced with steel structures on concrete piers and abutments, grades are being reduced, grade crossings eliminated, certain parts of the line double-tracked, and the interlocking of switches and signals is making steady progress. In the motive power department, 29 new freight engines and a number of new passenger and freight cars of various kinds were added, while 23 new boilers were built and 65 engines rebuilt at the railway shops.

The steam and electric tramways aggregate 124½ miles, with a capital cost of $16,857,935.

The financial results for the year are shown in the following table:

	Railways.	Tramways.	Total.
Earnings	$16,374,465	$3,760,170	$20,334,635
Expenses	11,331,495	3,270,825	14,602,320
Net earnings	5,242,970	489,345	5,732,315

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The fight of the Merchants' Association of New York city against the alleged faulty construction of the Jerome Park Reservoir has reached the Croton Aqueduct Commission, and that body is now hearing the evidence in the case. Particular effect has been made in the testimony so far presented to condemn the use of crusher dust in place of sand for mortar as responsible in part at least for the faults charged. There is no question as to the fact that stone dust from crushers was used where the specifications called for clean sharp sand. The only question at issue is whether the leaky reservoir walls are in any degree rightly chargeable to this fact. Obviously they are not, unless it can be shown that the stone dust used is inferior to sand as a mortar-making element, and so far this has not been demonstrated. Indeed, there is a large amount of both direct and indirect evidence to the contrary.

In some mysterious way it has been assumed that in using stone dust in place of natural sand for mortar at Jerome Park the engineers were inaugurating a new and unknown feature of practice in masonry construction. How far this assumption is from real truth was pointed out by the commission of eminent engineers whose report was published in our issue of Aug. 6, 1903, but it is well worth repeating at the present time in order that misleading ideas may not get abroad uncontradicted. Crushed stone dust was recognized by the cement authorities of 30 years ago as a permissible and suitable substitute for sand for mortar. It was used instead of sand in constructing the great Vyrnwy Dam for the Liverpool water-works, one of the most celebrated engineering works of the world. At the present time the well-known English engineer, James Mansergh, is using to the entire exclusion of natural sand the dust of his stone crushers in building the five great dams for the Birmingham water supply. The coast defense fortifications built in Boston Harbor in 1902-3 were constructed of concrete, using crusher dust in place of sand after a series of careful tests had demonstrated to the U. S. engineers in charge that the artificial material was the superior one. Numerous similar instances could be cited, but those quoted are sufficient to establish the fact that well known and conservative engineers see nothing to fear in the substitution of stone dust from crushers for natural sand as an element for mortar and concrete.

It may be argued, of course, that the crusher dust available for the Jerome Park Reservoir work is of an inferior quality for cement mortar. To offset this statement we have the specific evidence backed by unprejudiced tests of the engineer commission appointed to report upon this question. These eminent engineers in their report say:

> These fine screenings are shown on examination to be entirely free from dirt; they constitute in reality an artificial but clean, sharp sand, with a range in size of grain from fine to coarse. . . . They may be properly and satisfactorily used in place of sand both in mortar and concrete.

Those of our readers who wish to study the report in detail will find it printed in full in Engineering News of Aug. 6, 1903. In view of all these facts and of the further fact that the leaky condition of the Jerome Park Reservoir walls can be easily explained without reference to the quality of the martar used, it seems somewhat absurd to have the opinions and impressions of irresponsible witnesses that stone dust mortar must be blamed for the trouble again served up to the public as a reason for distrusting its appointed engineers.

An illustration of the need of foresight and of the expensiveness of remedying defects in planning city street systems is afforded by some figures now before the Board of Estimate and Apportionment of New York city. These figures relate to the cost of adding 20 ft. to the north side of 59th St., between Fifth and Second Aves., the necessity for which is due, in part, to the increased traffic from river to river that will follow the construction of the Blackwell's Island Bridge. The cost of this widening, for property damages alone, is placed by Mr. Nelson P. Lewis, Chief Engineer to the Board of Estimate and Apportionment, at $4,159,667. For the single short block between Fifth and Madison Aves., the estimated damages amount to $2,516,740. Without discussing whether the present need of a wider avenue at 59th St. could have been foreseen, it is unquestionably true that most cities are delinquent in the matter of recognizing the need of great main thoroughfares, and also negligent in providing radial or diagonal lines of communication. Obviously, the time to meet such needs at low cost is before buildings and real estate values mount far upward. Reverting to the case of 59th St., it may be noted that the New York "Tribune" has suggested that in place of widening the whole street the present curb lines, at least between Madison and Fifth Aves., be moved in to the property line, and the sidewalks be extended beneath the buildings, thus forming arcades at either side of the street, as in the case of the Rue de Rivoli, in Paris, or the famous arcades of Bologna. The idea seems worth considering before venturing on an expenditure of some $4,200,000 for damages alone.

The street cars, automobiles and other vehicles in the streets of New York were responsible for 125 cases of injury in two weeks, according to recent police records of that city. Of course, New York is a large city, but even after allowing for that, the number of street accidents seems unduly large. Illegally high speeds on the part of both ordinary vehicles and automobiles are held to be responsible for a large percentage of the accidents, it being a notable fact that many accidents occur where the street traffic is comparatively light. Inefficient or careless drivers and motormen are also responsible for many accidents, while doubtless a surprisingly large number are due to carelessness on the part of the injured. The remedies proposed are greater carefulness on the part of all concerned, more efficient police supervision, the exclusion of inefficient drivers and motormen, and power brakes for street cars.

A four-legged assistant to a city engineer in the Central West has been the indirect cause of no little trouble. It appears from a local paper that when the engineer was elevated from the position of assistant engineer to city engineer he offered to dispense with an assistant, as ordinarily understood, if the city would provide him with a horse and buggy. To this proposition the city fathers would not agree, but they did consent to pay for the feed of a horse if the city engineer would buy both horse and buggy. (The report does not say who paid for axle grease.) For some five years a horse served as a substitute for an assistant, "under republican and democratic administrations." Suddenly the mayor and the finance committee of the city council claimed that it was improper to allow the bills for the feed of the horse. The cause of this, the engineer states, was that he had stopped buying feed at the mayor's store. We leave to our readers the task of drawing a moral to fit this homely, but doubtless true, story.

The city of Providence, R. I., has long been known as one having a relatively low water consumption and a large percentage of its taps metered; two conditions which generally go together. Elsewhere in this issue will be found an abstract of a paper by Mr. J. Herbert Shedd, M. Am. Soc. C. E., giving some details of the meter system in that city, more especially with reference to its popularization and its effect on consumption. When the works were put in full operation in 1877 about 42 per cent. of the services were metered, and the consumption was 24 gallons per capita. The percentage of taps metered has been increased gradually year by year until it reached 84.4 per cent. in 1902. The consumption, as a rule, increased steadily until it reached 65.2 gallons in 1894; then it decreased year by year until it was 51.3 gallons in 1897; and since then it has risen slowly to 58 gallons in 1902. Some of the variations in per capita consumption may be due to the necessity of using estimated populations for inter-census years.

Mr. Shedd brings out clearly that where meters are not used water rates must be based on the estimated amount of water wasted. It also appears from his paper that the schedule rates at Providence have been so adjusted as to encourage the use of meters, while a minimum rate prevents such niggardliness in the use of water as would tend to unsanitary conditions or hamper the water department through a reduction in revenue below the actual cost of service. At Cleveland, O., the same general plan, but with modifications to suit local conditions, has recently been adopted to encourage the rapid introduction of meters, as shown in our issue of Oct. 22, 1903. At Cleveland, however, the minimum rate for small consumers is lower than at Providence, and the city furnishes, sets and repairs the meter at its own cost, while at Providence all this expense is met by the consumer. It is too early to say what the effect of meters at Cleveland will be on revenues, but they are cutting down waste and equalizing charges. The experience at Providence is generally accepted as proof of the beneficence of the meter system to both citizens and city. Mr. Shedd's review of the experience at Providence might well serve as an example to other engineers to study the effects upon consumption and revenue of both the meter and flat rate system of charging for water.

Recent inquiries have been made as to the present status of the plans for a Union Engineering Building in New York city to accommodate the national engineering societies, in accordance with the offer made by Mr. Andrew Carnegie last spring. It will be recalled that the offer of Mr. Carnegie was formally accepted by the Societies of Mechanical, Mining and Electrical Engineers and the Engineers' Club last summer, and that the American Society of Civil Engineers, at its Asheville meeting, instructed its Board of Di-

rection to send out a letter ballot, provided it is satisfied that suitable accommodations can be obtained, and that the acceptance of the proposition is otherwise practicable. This ballot must be presented to the Society with 60 days notice, and opportunity for discussion at the annual meeting.

In the New York "Herald" of Nov. 12, one of the representatives of the Engineers' Club is quoted as stating that the ballots had already been sent out to the members of the American Society of Civil Engineers, and that the answers are nearly unanimous in favor of the idea. This, however, is incorrect. The Board of Direction, we are informed, has been giving careful consideration to the placing of the matter of the Union House before the membership, following the instructions of the Asheville meeting. No ballot, however, can be sent out until after the annual meeting on Jan. 20, 1904. At that meeting the membership will be fully posted on the question by the circulars issued by the Board of Direction, and there will doubtless be a full discussion of the project.

As is well known, the limit of power capacity of electric power machinery is in most cases dependent upon the heating produced by lost work within the machine. The factors in fixing the limit are the internal lost work and the rate at which heat is dissipated from the machine. The former factor is fixed for a given machine, since its efficiency at given load is a fixed quantity. The rate of heat dissipation is a more complex factor; it varies with a number of elements; for example, it may be increased materially by thorough ventilation of the parts where the heat is produced. There is an analogy for this in the case of bearings or other sliding surfaces in machines: the permissible load, and hence the size and proportions of the parts, are dependent upon the amount and effectiveness of lubrication. Now when a bearing must be designed smaller than is desirable, or when it is subject to dust and dirt during operation, it must be more efficiently lubricated. Similarly, when an electric machine, say a motor, must run under unfavorable conditions, for example, when its heat-dissipating capacity is reduced by tightly enclosing the motor, or when it must be made small in proportion to its work, it should be more thoroughly ventilated so as to keep down its temperature-rise. Motors for electric cars work under both these conditions; they must be relatively small and light, and they require to be completely enclosed. Consequently the temperature rise is of especial importance in their case. A great amount of study has been put upon "railway motors" in recent years, to determine their heating under various typical operating conditions, in the endeavor to build the smallest motor for a given service. Strange to say, however, artificial ventilation to keep down their heating has never been resorted to, except possibly in an experimental way. In a recent instance, which was reported in electrical circles as something of a curiosity, ventilating pipes were led from the motor case to ventilator cones on the roof of the car, thus utilizing the motion of the car to ventilate the motors. A general adoption of ventilation for railway motors may come in the future; its advantages are considerable, and no material difficulties stand in the way. In many cases of stationary electrical machinery ventilation is of equal advantage. Transformers are the only machines to which artificial ventilation has been applied extensively hitherto. But motors in stationary service must often work under as unfavorable conditions as railway motors, and in such cases forced ventilation is of direct practical value. A motor installation for an automatic sprinkler pump, described in a brief note on another page, is an interesting example of its application. Here the motor had to be wholly enclosed so as to be waterproof, and reliability under extreme load conditions, as when a general fire opens all sprinklers, was of primary importance. Less pressing reasons will often justify applying a simple ventilating arrangement to an enclosed motor; usually nothing more would be needed than properly arranged air supply and discharge pipes, letting the motor armature itself act as fan.

WHEEL LOADS IN MODERN RAILWAY PRACTICE.

We print in this issue a recent Institution of Civil Engineers' paper, written by the Consulting Engineer of the Indian Government railways, on the limits of wheel loadings in railway service, which appears to us of interest to American railway engineers from many points of view.

In the first place it is worthy of notice that this paper, presented in the year 1903 before the great and famous Institution of Civil Engineers, is largely devoted to recording features of American practice and to quotations from papers read by American engineers before the American Society of Civil Engineers in 1889, or 14 years ago. That the matter presented in these papers was exceedingly interesting and valuable at the time they were read is beyond question; but American railway practice in the matter of wheel loads has so rapidly and greatly altered since the date these papers were read that their present interest is chiefly historical.

How great this change is can only be appreciated by going back and examining those old discussions. The author of one of the papers concluded it with the following sentence:

> In view of the facts just stated, the tendency to increase the weight of rolling stock seems to me to have passed its proper limits and that we should call a halt.

The late W. W. Rich, at that time Chief Engineer of the Minneapolis, St. Paul & Sault Ste. Marie Ry., said:

> Last year we modified the specifications of our freight cars (Minneapolis, St. Paul & Sault Ste. Marie Ry.), bringing them up from 40,000 to 50,000 lbs. capacity, and we have had about one thousand cars constructed on these specifications. I now consider that it was a mistake. If I had it to do over again I think I would not make cars—certainly not for general traffic—to exceed 40,000 lbs. capacity.
>
> The Master Car Builders' Association recently appointed a committee to determine the proper sized axle for a 60,000-lb. car. It seems to me that that committee ought to be discharged before they have time to report. So far as my observation goes, a car loaded to that limit has too great a weight per wheel load for the surface of the rails. I know of a railway company in Wisconsin that has tried some 60,000-lb. ore cars, and the Superintendent tells me they are for sale cheap.

The fourteen years since these statements were made have seen a growth in the size of railway rolling stock that has rendered obsolete practically everything that was then in service. The 40,000-lb., 50,000-lb. and 60,000-lb. car have each had their day, and then at a jump the 100,000-lb. car has been adopted as the standard for trunk-line service.

In the Institution paper by Mr. Spring, which we are considering, some recognition is given to this later practice, but the latest data which he uses are about four years old.

There is another point of view from which Mr. Spring's paper is of interest. It is the fact that in far away and benighted India it is deemed proper practice before designing and putting in service a new pattern of rolling stock to inquire of the engineer whether the rails are adapted to carry it. We do these things differently in the United States, and it is an open question whether we do them better.

The main feature of interest in Mr. Spring's paper is, of course, the method he proposes and the figures he names for setting the permissible limit of wheel loading. He is not, of course, the first to point out that the load to which a wheel may be subjected should vary with its diameter and with the width of the rail head; but he is the first, so far as we recall, to definitely adopt it as a practical basis for guidance in the design of rails and rolling stock.

The coefficient, or "Index Number," for wheel loads which Mr. Spring proposes for Indian Railways is 200; and the permissible wheel load in pounds therefore is 200 × inches width of rail head × diameter of wheel in inches.

It will be of interest to see how these figures compare with present day American practice. As our readers are aware, box and gondola cars of 100,000 lbs. and 110,000 lbs. capacity are now in extensive use. These cars are all carried on eight wheels. The weight of the empty car varies from 30,000 to 44,000 lbs. Taking 110,000 lbs. as the load—and very many coal and ore cars are now loaded with this amount—it will be seen that the total weight of such a loaded car will be in the vicinity of 150,000 lbs., or 18,750 lbs. per wheel.

Next to the width of the rail over which these loads are carried, it is probably true that such cars are very little run in general interchange. They are confined as much as possible to the home road, and the railways whose traffic demands the use of such cars are now equipped with fairly heavy rails. If we assume that such cars are run over 80-lb. rails of Am. Soc. C. E. section, worn down so that their full width of head is effective, we have a width of bearing of the wheel on the rail of 2½ ins. The coefficient or index number, therefore, becomes

$$\frac{18,750}{33 \times 2\frac{1}{2}} = 227.$$

It will be noted that Mr. Spring's coefficient of 200 is obtained from American practice of about four years ago. The above figure probably fairly represents the increase in rail loading that has taken place since that time through the increasing use of large capacity cars.

As to whether this is the limit of wheel loads which may be expected, opinions differ. It is true on the one hand that cars of larger capacity than this, designed for special classes of traffic, are already in service. The General Electric Co., for example, has two steel flat cars recently built, designed to carry a load of 120,000 lbs., and capable of carrying a 10% overload if a particularly heavy casting or piece of machinery demands it. The dead weight of these cars is 47,500 lbs.; hence, when carrying their maximum load they will have a total weight of 179,500 lbs., or 22,430 lbs. per wheel, since the car has only eight wheels. Besides this, the wheels of this car are only 28 ins. diameter, and when run on rails 2½ ins. wide, the "Index number," as Mr. Spring terms it, would, therefore, be:

$$\frac{22,430}{28 \times 2\frac{1}{2}} = 320.$$

We do not believe, however, that such wheel loads are likely to come into anything like general use. Experience with existing 100,000-lb. cars has shown that we have about reached the limit of what cast-iron wheels will stand, and while some strengthening of the wheels is possible, the flange thickness cannot be increased. Where it is necessary to build cars for special service of greater capacity than 100,000 to 110,000 lbs., the proper thing to do is to use six-wheel trucks.

Regarding the basis on which Mr. Spring's proposed limit is made up, we take it that no American engineer will now question the fact that the allowable load on the wheel varies directly with the width of the rail head. The monumental contribution of Mr. D. J. Whittemore to engineering literature in his paper on "Cylindrical Wheels and Flat-Topped Rails," from which Mr. Spring so liberally quotes, turned engineers' ideas in the right direction. The old ideas of coned wheels and rounded top rail heads have been completely discarded, and it is now recognized that a wide rail head giving a longer line of contact with the wheel is a distinct advantage.

Concerning the other factor in Mr. Spring's equation, however, there is room for much difference of opinion. No one will question that a wheel of large diameter can safely be loaded more heavily than a wheel of small diameter; but there is no reason why its safe load should be exactly proportional to the diameter. If such a proportion existed, then a 66-in. locomotive driving wheel might be loaded to 37,500 lbs. without producing greater strain on the rail surface than an eight-wheel loaded freight car weighing 150,000 lbs., or 18,750 lbs. per wheel.

The heaviest locomotives now in service have a maximum driver load of 26,000 to 28,000 lbs. Is it true that this load is less severe on the rail and wheel contact surfaces than the load imposed by the 100,000-lb. steel cars now in service?

Not only practical experience but theory is opposed to such an idea. If we suppose a cylindrical wheel of 1-ft. diameter and a wheel of 10-ft. diameter to touch a plane but to bear no weight upon it, the contact in each case will be along a mathematical line. As load is imposed on the wheel, compression takes place in the rail and wheel surfaces, and is a maximum along the original line of contact, reducing to zero on either side a short distance away. Now the only reason why more

load can be safely imposed on the wheel of large diameter than on the wheels of small diameter is that it is, so to speak, blunter than the smaller wheel, so that more surface comes into contact with a given pressure. In both wheels, however, the pressure is greatest along the original line of contact and in both wheels also the actual surface of contact is only a very small fraction of an inch in width. It is hardly reasonable to believe, therefore, that the 10-ft. wheel can carry ten times the weight of the 1-ft. wheel with no more risk of injury to the surfaces under pressure.

This point is one of no small practical importance in rolling-stock design, particularly in connection with the design of locomotives with small drivers for switching service, or mountain grades, and of electric locomotives, where small drivers are the rule. If it is true that the safe load varies directly with the diameter of the wheel, the fact ought to be proved; and if it is not true, it would be of interest to have the real ratio of variation determined.

LETTERS TO THE EDITOR.

A Query as to Spreading Spoil Banks.

Sir: I have under consideration the design and the drawing of specifications for several large drainage ditches which will no doubt be constructed by some form of ditching dredge. A number of the land owners through whose lands the ditches will be constructed have requested me to specify that the spoil bank or dump shall be spread. As I have never heard of a piece of work of this kind where it was required to spread the spoil bank, I shall be very grateful to the readers of Engineering News for any information on the subject, especially the cost of spreading the spoil bank, and to what extent the same was spread, the method of working the same, and how soon after depositing the bank can it be worked best.

Respectfully yours, S. F. Moeller,
County Surveyor for Calhoun County, Ia.

Knierim, Ia., Nov. 10, 1903.

More Concerning Photo-Reproductive Processes.

Sir: I enclose several prints from the same positive tracing. No. 1 is a negative print on a brown process paper. This is then used to obtain the positive prints Nos. 2 and 3, which are on brown and blue process papers giving brown and blue lines respectively on a white ground. No. 4 is an ordinary blue negative print, and No. 5 is a positive print giving black lines on a white ground. This paper requires solely a water bath and the print is taken directly from the tracing. The brown paper requires a salt bath which I think attacks the fiber of the paper and makes it more or less brittle.

The black process paper (as well as prints Nos. 2 and 3 from No. 1) admits of coloring, as you see. All the papers are on the market, but perhaps the black process paper is little known. Very truly yours,

A. S. Ackerman.

Naval War College, Newport, R. I., Nov. 9, 1903.

(We regret that it is impossible to reproduce the interesting exhibit which our correspondent sends. It is certainly a fact that the processes of reproduction other than the blue-print process are less known and used by engineers than they should be, as our recent correspondence published in this column has made clear. Engineers can greatly facilitate the work of contractors if they will furnish brown prints or white prints on their paper instead of the usual blue prints.—Ed.)

Notes and Queries.

F. N. writes that he intends taking the examination for inspector on the Barge Canal work, and wants to know what books to consult in preparing for the examination.

Canal work consists largely of excavation, masonry and piling; hence, Baker's "Masonry" ($5), and Gillette's "Earthwork" ($2) may be studied with advantage. Byrne's "Inspection of Materials" ($3) is written especially as a hand-book for inspectors, and should be consulted, especially when questions on steel construction are to be asked in examination. The book also contains many facts and figures on masonry and concrete abstracted from Baker's "Masonry," but the treatment of earthwork is very short. If only one book is to be purchased, then Byrne's "Inspection of Materials" should be the one; but he who wishes to prepare himself thoroughly for an examination, such as this, can seldom afford to rely upon one book alone.

In the article on "Central Heating Plants" in our issue of Nov. 5, the two engine-dynamos of the Century Building were given as 50 and 30 KW. This should have been 50 and 80 KW.

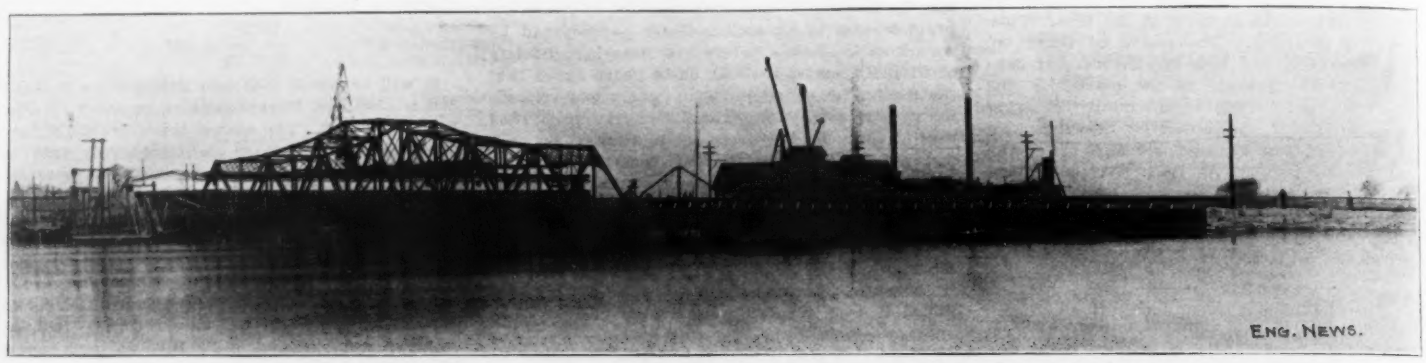


FIG. 1. GENERAL VIEW OF HIGHWAY BRIDGE ACROSS WEYMOUTH FORE RIVER, MASSACHUSETTS.
Hildreth & Co., New York, Engineers; Fore River Ship & Engine Co., Quincy, Mass., Builders.

AN AMERICAN BRIDGE BUILT OF GERMAN STEEL AND LAUNCHED AT A SHIPYARD.

By P. S. Hildreth.*

In 1900 the legislature of Massachusetts provided for the construction of a draw bridge over the Weymouth Fore River, between Quincy and Weymouth, Mass., to replace an old wooden structure built originally in 1808. The conditions of location were in no way extraordinary, nor were the requirements of maintenance of navigation and street traffic, except as the former was affected by the recent construction of the large ship building works of the Fore River Ship & Engine Co., on property immediately above the bridge site and the necessity of early completion in order to permit the delivery of the large seven-masted schooner "Thomas W. Lawson," and one of the cruisers for the U. S. Government. The conditions affecting the cost of construction, while not unusual, offered greater difficulties to overcome. The Board of Norfolk County Commissioners, in charge of the construction were anxious to accomplish a permanent and creditable piece of work, the local authorities of Quincy and Weymouth desired a double roadway and double sidewalk clear of the electric railway tracks of the Old Colony Street Ry., the Fore River Ship & Engine Co. required early completion, the cost of steel work was rapidly advancing and the time of probable delivery retreating, all of which conditions were to be met by a limited appropriation made when the cost of similar work was twenty to forty per cent less.

The Commissioners retained the writer as designing and supervising engineer, who recommended that an additional appropriation be secured and submitted plans calling for a pin-connected or riveted, lattice truss, draw span, 264 ft. long, approaches of plate girder spans, each 68 ft. long, and earth fills with retaining walls. An effort to let the contract resulted in three bids, no one of which was within 30% of the available appropriation or such as to assure completion within the time desired. Efforts to secure an additional appropriation failed. A second letting was then advertised and the Fore River Ship & Engine Co. decided to bid on the contract in view of their interest in the prompt construction and their facilities to assist sub-contractors both with plant and materials for the substructure and approaches. This company submitted a low bid within the appropriation and were awarded the contract. They had used a sub-bid for the superstructure from one of the large bridge companies but after three months delay these parties declined to proceed with the work.

With four months lost, prospect for prompt construction seemed more than doubtful and meanwhile the price of steel and manufacture had further advanced and promise of delivery of steel

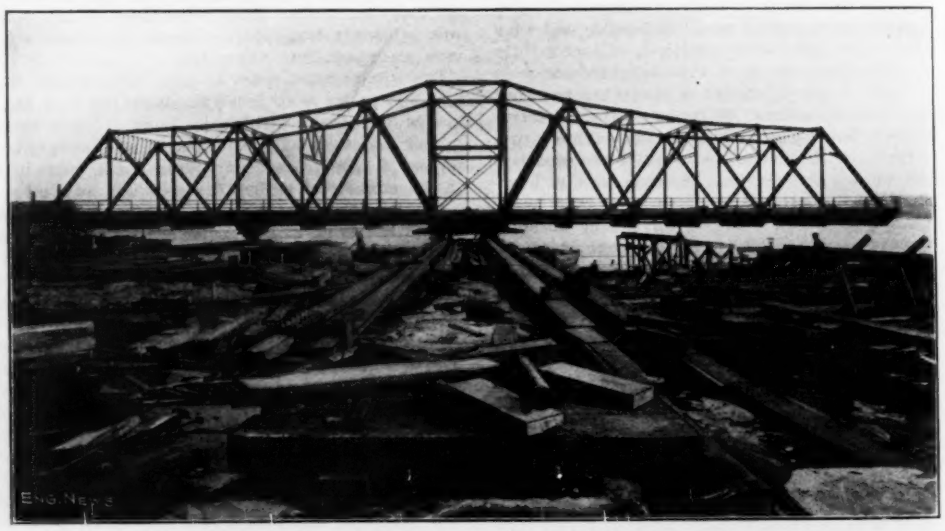


FIG. 2. SWING SPAN OF FORE RIVER BRIDGE MOUNTED ON SHIP WAYS READY FOR LAUNCHING.

*Hildreth & Co., Engineers, 30 Broadway, New York, N. Y.

from this country within nine months could not be secured.

At the suggestion of the engineer the plans were modified to permit the economical use of steel sections rolled in Germany and the Fore River Ship & Engine Co. undertook to do the work in their own shops. A representative of the engineer was sent abroad and an excellent quality of open hearth steel secured. Delivery was made within three months and shop manufacture started immediately thereafter.

The interesting features of the work were the method of shop manufacture and erection. The fact that the bridge site was within half a mile of the shops suggested the shop construction of the several spans with all parts in place and floating into position, but the change of grade between the old structure and the new, made it desirable that the erection of the entire structure should be accomplished at practically the same time. The work was therefore laid out to rivet the spans complete in the order in which they would be floated into position but all located on ships ways at a considerable distance from the

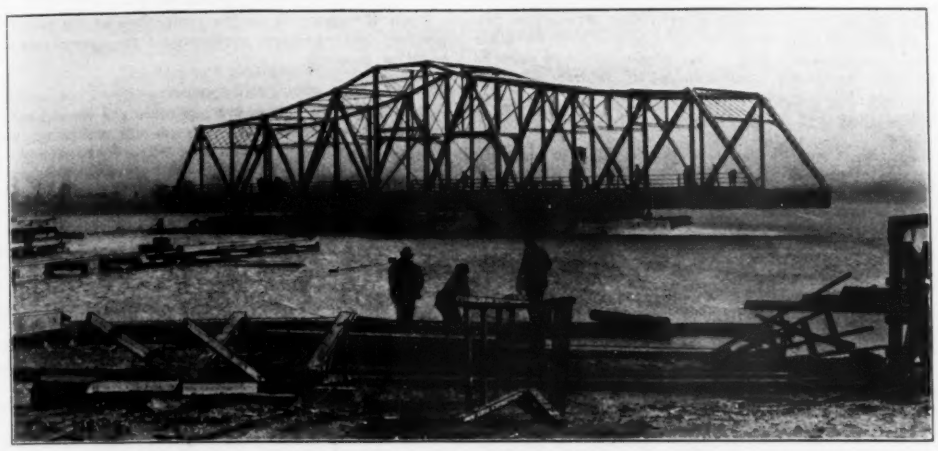


FIG. 3. SWING SPAN OF FORE RIVER BRIDGE ON BARGES READY FOR FLOATING INTO POSITION ON PIER.

water's edge and within reach of derricks, power and compressed air for reaming and riveting. When completed, each span was raised, rollers were run under and it was practically launched to a loading platform built over the water. Scows were then floated beneath at low tide and each span successively lifted, towed to the site, accurately located and left in position with the falling tide. One scow was sufficient for each of the approach spans and two for the draw span. The handling of the latter is well shown by the accompanying photographs.

There is nothing new in the floating of a complete bridge span into position but there is novelty in launching a bridge and much that is creditable in the construction of an important draw span by a ship building company and particularly in the quick and economical method of erection by which interference with traffic was minimized. It is of interest also that in spite of the delays the structure was practically complete at the date originally set and at a time when trade conditions were such that all steel work was much delayed in delivery; incidentally there was a saving to the state of approximately $30,000. The work done by the Fore River Ship & Engine Co. was in charge of Mr. M. M. Cannon, Civil Engineer of the company. Referring to the illustrations, Fig. 1 is a view of the completed bridge; Fig. 2 shows the swing span at the foot of the ship ways ready for floating, and Fig. 3 shows the same span on the barge and being floated into position on the foundations.

RECENT PROGRESS IN THE DESIGN OF LOCOMOTIVE FRONT-ENDS.*

By W. F. M. Goss, M. Am. Soc. M. E.†

The term "front-end" refers to all that portion of a locomotive boiler which is beyond the front tube-sheet. It includes the extending shell of the boiler which forms the smoke-box, and in general all mechanism which is therein contained, such as steam and exhaust pipes, nettings, diaphragms, draft pipes. It also includes the stack.

The front-end as thus defined is to be regarded as an apparatus for doing work, receiving energy from a source of power, and delivering a portion thereof in the form of a specific result. The source of power is the exhaust steam from the cylinders, and the useful work accomplished is represented by the volumes of furnace gases which are delivered against the difference of pressure existing between the smoke-box and the atmosphere. That the power of the jet may be sufficient, it is necessary that the engines of the locomotive exhaust against back-pressure. The presence of the back-pressure tends to lower the cylinder performance, and it is for this reason that designers of front-ends have sought to secure the required draft action in return for the least possible ratio of draft to back-pressure, which ratio has been defined as efficiency of the front end.

DISTRIBUTION OF DRAFT.*

The office of the front-end is to draw atmospheric air into the ash-pan thence through the grate and fire; to draw the furnace gases through the tubes of the boiler, thence under the diaphragm and into the stack, from where they are forced out into the atmosphere. In order that this movement may take place, a pressure less than that of the atmosphere is maintained in the smoke-box, so that when the locomotive is working there is a constant flow from the atmosphere along the course named and back to the atmosphere again. The difference in pressure betwen the atmosphere and the smoke-box is spoken of as the draft and, under normal conditions of running, is usually represented by from 4 to 6 ins. of water. The draft thus expressed, however, is greater than that to which the fire is actually subjected. Thus: Approximately, a third of the total draft is required to overcome the resistance of the ash-pan and grate together with the fire thereon. Another third is required to overcome the resistance of the tubes, and another third to overcome the resistance of the diaphragm.

THE ACTION OF THE EXHAUST JET.†

Prior to the publication of the Master Mechanics' Proceedings for 1896, it had been common to assume that the action of the exhaust jet was similar to that of a pump, that the exhaust from each cylinder-end supplies a ball of steam which fills the stack very much as the piston of a pump fills its cylinder, and which, by virtue of its own momentum, pushes before it a certain volume of the smoke-box gases until it passes out of the top of the stack. In obedience to this theory, earlier experimenters had given much attention to a determination of the angle made by the jet of exhaust steam, to the end that the stack should be so proportioned that the diameter of the jet would agree with that of the stack at the point of initial contact. This theory is no longer acceptable. It has now been shown by means of delicate apparatus, which need not be here described, that the jet of steam does not fill the stack at or near the bottom, and that on certain conditions common to practice it touches the stack only when it is very near the top. The action of the jet is not that of a pump, as has been previously supposed, but rather one of induction; the exhaust-jet does not push the gases before it, but draws them to itself and thence into the atmosphere.

But the action is not entirely that of induction. A study of different portions of the exhaust jet shows that different portions of the jet have different velocities. The interior portions of the jet have a much higher velocity than the exterior portions which, it may be presumed, are retarded through their contact with the smoke-box gases to which a portion of their initial energy has been imparted. Thus, the center of the issuing stream is composed chiefly of steam while its outer portions are heavily loaded with the smoke-box gases. The sparks and cinders are principally discharged from the outer portions of the stream.

The power of the exhaust jet, other things being the same, is not dependent upon any condition of running. It does not change when the speed and cut-off are changed. It depends chiefly upon the rate at which steam is delivered from the exhaust tip. If the weight of steam exhausted per unit of time is unchanged, the locomotive may be at rest with its valves blocked up, it may be worked at a slow speed and long cut-off, or at a high speed and short cut-off, and in each case the draft will be the same. On the other hand, any change in the weight of steam exhausted affects the draft, and herein is evidence of the excellent condition of balance which exists in a locomotive between the rate of evaporation and the condition of the fire which produces it. Whenever, by any change in running, there is an increase in the weight of steam exhausted, the draft is strengthened, the rate of combustion augmented, and the evaporation of the boiler is increased.

Summarizing the foregoing statements, the facts which are now well established concerning the action of the exhaust-jet may be stated as follows:

1. The jet acts upon the smoke-box gases in two ways; first, by frictional contact, it induces motion in them, and, second, it enfolds and entrains them. The action is chiefly that of induction.

2. The action of the jet upon the smoke-box gases is to draw them to itself so that the flow within the front-end is everywhere toward the jet.

3. The action of the jet is not dependent upon the impulses resulting from individual exhausts. Draft can be produced by a steady flow of steam as by the intermittent action of the exhaust.

4. Draft resulting from the action of the jet is nearly proportional to the weight of steam exhausted per unit of time. It does not depend upon the speed of the engine nor the cut-off of steam from the cylinders, except in so far as these affect the weight of steam exhausted.

5. The form of the jet is influenced by the dimensions of the channels through which it is made to pass. Under ordinary conditions, it does not fill the stack until near its top. If the diameter of the stack is changed, that of the jet will also change.

FORM OF THE EXHAUST NOZZLE.

Two general forms of exhaust pipe and nozzle have for many years been in common use, one a "double pipe and nozzle," in which the exhaust steam from each cylinder follows a separate passage throughout its course to the point where it is delivered, and the other, a single exhaust pipe and nozzle in which the exhaust steam from both cylinders is brought together to form a single jet before delivery. The double exhaust pipe might, so far as its function is concerned, be made up of two separate castings, but for convenience the parts are combined. Many other forms of exhaust pipes have been used, and are still in service, but the probability is that none possessed exceptional advantages as compared with the two forms mentioned. As one of the conclusions of their long and laborious investigation of 1896, the Master Mechanics' Committee found but little difference in the efficiency of the single and double nozzle when each is properly proportioned to its work, though incidental reasons seem to favor the single nozzle. The committee therefore concurred in the recommendation of the previous committee in recommending that the single nozzle be adopted for general use.

HEIGHT OF BRIDGE IN PIPE.†

It has been shown beyond question that the lower the exhaust tip, the better will be the draft. From the data derived from the tests of the "American Engineer," it should be possible to derive an expression, showing the change in draft power resulting from given changes in the height of the nozzle, but thus far such an expression has not been proposed. It may be said, however, that the gain in draft power which may be had by lowering the nozzle even a few inches is sufficient to justify some sacrifice of convenience if the arrangement of other details demand it. The Master Mechanics' Committee of 1896 expressed the belief that in view of the other apparatus to be accommodated in the front-end, it will be found impracticable to have the exhaust-pipe less than 19 ins. in height.

HEIGHT OF BRIDGE IN PIPE.*

An essential feature of the single exhaust pipe is the so-called bridge which maintains a separate steam pas-

*Extracted from a paper read before the Central Railway Club, Nov. 13, 1903.

†Dean, Schools of Engineering, Purdue University, Lafayette, Ind.

*Locomotive Draft Appliances, American Engineer, May, 1902.

†The American Railway Master Mechanics' Association as early as 1890 had appointed a committee to report on the best forms of exhaust nozzles and steam passages which committee, after making one report, and after being continued for several years, finally gave way to a new committee under the chairmanship of Mr. Robert Quayle, with the result that in 1896 an epoch making report was presented. The work of this committee settled two important questions, namely, the action of the exhaust jet, and the form for exhaust pipes and nozzles. The facts presented in this paragraph are largely drawn from this report.

*Report on Exhaust Ports and Steam Passages, Proceedings A. R. M. M. A., 1896. Also, Locomotive Draft Appliances, American Engineer, December, 1902, and May, 1903.

†Report on Exhaust Ports and Steam Passages, Proceedings A. R. M. M. A., 1896.

sage for each cylinder for a portion of the length of the pipe. It is above the top of this bridge only that the steam exhausted from both sides of the locomotive intermingles. The purpose of the bridge is a two-fold one. It prevents the exhaust of one side from blowing through into the exhaust passage of the other side, and when properly designed it is the means of making that side from which the strongest stream is passing assist by induction the exhaust from the other side. To determine the best height of the bridge, exhaust pipes of four different designs were tested by the Master Mechanics' Committee, all being the same except in the height of the bridge and in the proportions of those parts adjacent thereto. The conclusion of the committee was that whenever the bridge was less than 12 ins., some loss of efficiency resulted, though such loss was not great even when the height of the bridge was reduced to 5 ins. They recommend that the bridge be not less than 12 ins. They recommend also, that where long exhaust pipes must be employed, that the increased length should always be secured by extending that portion of the pipe which is above the bridge. This recommendation in effect contemplates a constant height of bridge for all lengths of pipes.

AREA OF CHOKE.*

That part of the steam pipe betwen the bridge and the outside wall where the contraction of the passage is greatest has generally been referred to as the "choke." An early committee had recommended that the area of the choke be 80% of that of the nozzle, and the committee of 1896 did a large amount of work upon pipes having this proportion. Not satisfied, however, with the validity of the conclusions, the later committee extended its research to involve a large range of proportions, with results sustaining the conclusions: First, that the area of the choke must not be less than the area of the nozzle, and, second, that whenever with a given pipe it is necessary to sharpen the exhaust action, the result should be secured by contracting the nozzle, and not by contracting the choke.

USE OF BARS OR CROSSES OVER THE NOZZLE.

It is well known that engines which refuse to steam may sometimes be made to do so by bridging the exhaust nozzle with a small piece of round iron or by a bar or bars having a knife edge cross-section designed to spread the jet and at the same time impede its motion as little as possible. Experiments were therefore made by the committee of 1896 both upon round bars and upon crosses, with results confirming previous experience upon the road. It was found that by spreading the jet by means of such devices the draft could be improved, but in all cases the presence of the bridge so much increased the back pressure that the efficiency of the front-end was reduced. In other words, the presence of the bar or cross produced the same effect upon the back pressure as the substitution of a smaller nozzle without the bars. They found that cross bars not wider than ⅝-in., and having the lower portion shaped to a sharp knife edge, placed on the nozzle or any distance not greater than one inch above it, increased the back pressure, and that crosses having wider bars increased the back pressure at a greater distance from the nozzle. In view of these facts, and, also in view of the fact that all evidence goes to show that for highest efficiency the jet should be kept as well compacted as possible, the practice of splitting it up is not to be commended. It is better practice in cases where the draft is unsatisfactory to reduce the diameter of the exhaust nozzle than to attempt to secure the desired result by employing a larger nozzle with a bridge above it.

THE STACK PROBLEM.

A few years ago there were undertaken at Hanover, Germany, an elaborate series of tests designed to solve the stack problem. The results, which in this country have since been known as those of the von Borries-Troske tests, have been widely published. They were conducted upon a full-sized model front-end, steam being supplied from a stationary boiler, and air in imitation of the smoke-box gas being admitted to the front-end through a restricted opening. While they have undoubtedly served well to guide the practice of German railways, they have not greatly influenced that of our own country. When, therefore, the "American Engineer and Railway Journal" offered to act as patron for a series of stack tests, to be run upon the experimental locomotive of Purdue University, and when the Trustees of Purdue University met this offer by contributing the use of its equipment and the time of its expert staff, a field of research which previously had been quite neglected was entered upon. In the course of these tests, straight stacks and tapered stacks were used, each form being represented by four different diameters and five different heights, so that in effect there were twenty different straight stacks and twenty different tapered stacks employed. Each of these stacks was tested in connection with seven different heights of nozzle and for many of them results were repeated under different conditions of speed and for different conditions of cut-off, so that altogether something more than a thousand distinct tests were made.

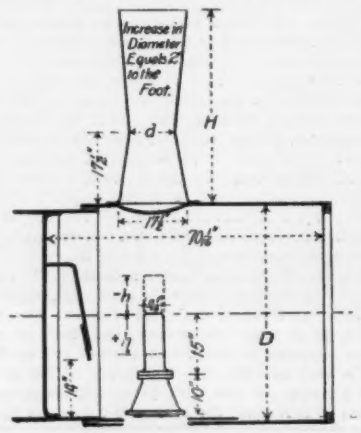
The experimental locomotive is a normal American type engine having a front-end 54 ins. inside diameter. Its mounting in the laboratory is such that it may be run under any condition of load or speed in precisely the same manner as upon the road. The results obtained confirm statements previously made from the Purdue laboratory to the effect that the efficiency of the front-end is not dependent upon the speed, cut-off or other conditions of running.

Moreover, it appears that a departure from correct proportions in the case of the tapered stack is less harmful in its effect upon draft than in the case of the straight stack. For these reasons the tapered is to be preferred, and that which follows will chiefly concern this form. For the purpose of this presentation the tapered stack must be understood as one having its smallest diameter at a distance 17½ ins. from the base, above which point its diameter increases at the rate of 2 ins. per foot, these being the proportions of the experimental stacks by the use of which the following conclusions were reached. It should be noted, also, that the relations stated in the paragraphs which follow, with reference to stacks, are those which are known to apply to front-ends 54 ins. in diameter. It is assumed that by employing the diameter of front-end as a unit of measure, they may be made to apply to any diameter of front-end. The assumption is a logical one, but its validity has not yet been absolutely proven.

PROPORTIONS OF A TAPERED STACK.

The height is an important factor in a stack, and in general, the greater the height of stack, the better will be the draft. So far as present information indicates, there seems to be no substitute for height; that is, that there is no change in the proportion of the stack itself and no change in the relation of stack and nozzle which will compensate for loss of height. It remains, therefore, to always make the stack as long as possible, and, having done this, to design the surrounding parts for maximum efficiency. For best results, a tapered stack at its point of greatest contraction should have a diameter equal to one-fourth the diameter of the front-end. This is true whether the stack is long or short.

A diagram of the front-end, indicating conditions under



which these equations apply is shown herewith, and a tabulated statement of stack diameters applying to front-ends of various diameters, and of various heights, is given in the accompanying table.

A front-end arrangement which is efficient at one speed will be found efficient at all speeds, and an arrangement which is satisfactory at one cut-off will be found satisfactory at all cut-offs. These are facts which should prove important to future experimenters who, by accepting them, may avoid multiplying observations by changing conditions of running. When the facts are known concerning a single condition, there is nothing to be gained by further increasing the number of tests.

FORM OF STACK.

An equal degree of efficiency can be secured by means of either the straight or tapered form of stack. As a problem in design, the tapered stack is the more simple, since its diameter for best results is not affected by changes in height. The straight stack, on the other hand, must have a different diameter for each different height. Assuming that the results obtained from a single experimental engine are sufficient to justify a general equation for the diameter of stack,

$$d = .25\ D$$

in which d is the diameter of tapered stack at the point of greatest contraction when the exhaust tip is in the center line of the boiler, and D is the diameter of the front-end of the boiler. The diameter of stack is affected slightly by changes in the height of the nozzle. It should be diminished as the nozzle is raised and increased as the nozzle is lowered. Calling N the distance in inches between the center line of boiler and the exhaust nozzle, the extent of the change which must thus be introduced may be expressed as follows:

When the nozzle is below the center of the boiler,

$$d = .25\ D + .16\ h$$

When the nozzle is above the center line of the boiler,

$$d = .25\ D - .16\ h$$

When the nozzle is on the center line of the boiler, h becomes zero, the term containing it disappears, and the equation becomes,

$$d = .25\ D$$

THE STRAIGHT STACK.*

As stacks of this form are not especially recommended, no detailed discussion need be given. Equations applying to a straight form of stack may, however, be written as follows:

When the exhaust nozzle is on the center line, h is equal to zero and the last term disappears and there remains

$$d = (.246 + .00123\ H)\ D$$

When the exhaust nozzle is below the center line of the boiler,

$$d = (.246 + .00123\ H)\ D + .19\ h$$

When the exhaust nozzle is above the center line of the boiler,

$$d = (.246 + .00123\ H)\ D - .19\ h$$

In these equations, d is the diameter of stack, H the height of stack, D the diameter of the front-end, and h the distance between the center line of boiler and the exhaust nozzle. All dimensions in inches.

In conclusion, it will be seen that investigations already made have served to make clear the action of the exhaust jet, and the condition of pressure which stimulates the currents of air and furnace gases throughout the course from the ash pan to the top of the stack. Existing data are sufficient, also, to guide in the design of the exhaust pipe and tip for maximum results. All this is to be accepted as a certainty. In addition, the probability is that we may design stacks for maximum efficiency though the statement must be subject to some qualification until the experiments already made at Purdue have been checked by trials involving larger engines either upon the road or testing plant. This settled, there remains of those elements which characterize the modern front-end, the problem of the draft-pipe, of the inside stack, by which is meant a stack extending down ward into the front-end and terminating in a bell-shaped end, and of the inside stack in connection with a false top within the smoke-box. All of these questions are now under consideration by a committee of the Master Mechanics' Association, under the chairmanship of Mr. H. H. Vaughan, whose interest in the subject makes it not unreasonable to expect that within the next two years all portions of the front-end may be correctly designed by aid of logical formulæ.

Table giving the diameter of taper stacks at the choke, in inches, for various diameters of boiler and positions of exhaust nozzle tip. (Taper of stack, 2 ins. per ft.)

Front End of Boiler; Diameter in Inches.	Distance Between Center Line of Boiler and Top of Exhaust Tip. Inches.									
	Tip Below Center.				Tip on Centre.	Tip Above Center.				
	20	15	10	5		5	10	15	20	25
30	....	....	9.1	8.3	7.5	6.7	5.9	....	....	....
32	....	....	9.6	8.8	8.0	7.2	6.4	....	....	....
34	....	10.9	10.1	9.3	8.5	7.7	6.9	....	....	....
36	....	11.4	10.6	9.8	9.0	8.2	7.4	....	....	....
38	12.7	11.9	11.1	10.3	9.5	8.7	7.9	7.1	....	....
40	13.2	12.4	11.6	10.8	10.0	9.2	8.4	7.6	....	....
42	13.7	12.9	12.1	11.3	10.5	9.7	8.9	8.1	....	....
44	14.2	13.4	12.6	11.8	11.0	10.2	9.4	8.6	....	....
46	14.7	13.9	13.1	12.3	11.5	10.7	9.9	9.1	8.3	....
48	15.2	14.4	13.6	12.8	12.0	11.2	10.4	9.6	8.8	....
50	15.7	14.9	14.1	13.3	12.5	11.7	10.9	10.1	9.3	....
52	16.2	15.4	14.6	13.8	13.0	12.2	11.4	10.6	9.8	....
54	16.7	15.9	15.1	14.3	13.5	12.7	11.9	11.1	10.3	9.5
56	17.2	16.4	15.6	14.8	14.0	13.2	12.4	11.6	10.8	10.0
58	17.7	16.9	16.1	15.3	14.5	13.7	12.9	12.1	11.3	10.5
60	18.2	17.4	16.6	15.8	15.0	14.2	13.4	12.6	11.8	11.0
62	18.7	17.9	17.1	16.3	15.5	14.7	13.9	13.1	12.3	11.5
64	19.2	18.4	17.6	16.8	16.0	15.2	14.4	13.6	12.8	12.0
66	19.7	18.9	18.1	17.3	16.5	15.7	14.9	14.1	13.3	12.5
68	20.2	19.4	18.6	17.8	17.0	16.2	15.4	14.6	13.8	13.0
70	20.7	19.9	19.1	18.3	17.5	16.7	15.9	15.1	14.3	13.5
72	21.2	20.4	19.6	18.8	18.0	17.2	16.4	15.6	14.8	14.0
74	21.7	20.9	20.1	19.3	18.5	17.7	16.9	16.1	15.3	14.5
76	22.2	21.4	20.6	19.8	19.0	18.2	17.4	16.6	15.8	15.0
78	22.7	21.9	21.1	20.3	19.5	18.7	17.9	17.1	16.3	15.5
80	23.2	22.4	21.6	20.8	20.0	19.2	18.4	17.6	16.8	16.0
82	23.7	22.9	22.1	21.3	20.5	19.7	18.9	18.1	17.3	16.5
84	24.2	23.4	22.6	21.8	21.0	20.2	19.4	18.6	17.8	17.0
86	24.7	23.9	23.1	22.3	21.5	20.7	19.9	19.1	18.3	17.5
88	25.2	24.4	23.6	22.8	22.0	21.2	20.4	19.6	18.8	18.0
90	25.7	24.9	24.1	23.3	22.5	21.7	20.9	20.1	19.3	18.5

*Report on Exhaust Ports and Steam Passages, Proceedings A. R. M. M. A., 1896.

THE RUHMER PHOTO-TELEPHONY has been utilized for a system of short-distance wireless telegraphy. The arrangement of apparatus for this use is as follows: The current supplying the transmitting arc-lamp projector or searchlight goes through one winding of an induction coil, in the other winding of which is a mercury interrupter, a Morse sender, and an auxiliary current supply. When the interrupter is in action it impresses a rapid undulation upon the lamp current, and consequently results in a similar undulation of the light intensity. At the receiving station the light received from the transmitting lamp is concentrated on a selenium cell connected with a telephone receiver. The undulations in the intensity of the projected light produce a uniform buzzing tone, which indicates that the mercury interrupter at the sending station is in action. Now, by means of the Morse telegraph key in the interrupter circuit, this latter circuit is opened and closed just as in an ordinary telegraph circuit. When it is opened, the buzzing in the receiving telephone ceases, since the transmitting lamp then burns steadily; when the key is again pressed down the buzzing is re-established. By this means messages sent in ordinary telegraphic manner are received in the telephone, where the signals may be taken off as from a telegraph sounder. The variation in the intensity of the

*Locomotive Front-Ends, "American Engineer," May, 1903.

searchlight is too slight and too rapid to be detected by the eye or any other means than a selenium cell, so that almost absolute secrecy of working is ensured. It is thought that this method of signaling may prove of great value for military purposes; the fact that it is limited to short distances makes it of little value for other uses. The necessary apparatus and instruments are made by the Siemens-Schuckert works, of Berlin, Germany.

A MOTOR WITH ARTIFICIAL VENTILATION has been installed recently in Chicago. A fire pump in the basement of the wholesale store of Marshall Field & Co. is driven by a direct-current motor which is enclosed in a water-tight case to enable it to operate even when submerged. To keep down the working temperature of the motor a fan is mounted on its shaft, between the armature and the pinion-end bearing, and two wrought-iron pipes are run from the motor-case to the street level for the supply and discharge of the ventilating blast. The pump, which supplies the automatic sprinkler system of the building, is an 8½ × 12-in. duplex pump, of the Laidlaw-Dunn-Gordon Co. The motor is a 100-HP. shunt-wound machine for 230 volts pressure, made by the General Electric Co. An automatic controller, governed by a pressure-regulator in the sprinkler system, starts the motor when the water pressure falls below 100 lbs. per sq. in.

STAYBOLTS FOR LOCOMOTIVE BOILERS.*

By H. A. Fergusson.†

There are few men connected with the mechanical departments of our railways who have not given more or less thought to the question of staybolts, and in many cases opinions have been formed which are based on the experience derived from local conditions, rather than from a general study of the subject, and the object of this paper will be to present on general lines some of the most frequent causes of staybolt failures, and also to indicate the most rational means for correcting or minimizing the trouble.

The greatest cause of broken staybolts is expansion and contraction of the firebox sheets, and it therefore follows that firebox design has a direct relation to staybolt breakage, and this fact is generally entirely ignored in designing new boilers. We scheme for larger grate area and increased heating surface; squabble over flue spacing and circulation, and then, when these and other elements satisfy us, stick in the staybolts at so many per square foot. Does any one deny that the long narrow fireboxes, curving sharply outward to a broad crown sheet were designed with little or no regard for effect on staybolts? Or that staybolts screwed into a comparatively thin sheet at an angle of say 75° will not soon prove troublesome? It is pleasing to know that our latest wide fireboxes eliminate all sharp curves in the side sheets, and consequently benefit the staybolts.

Since the relative difference in expansive movement between the outer and inner firebox sheets remain constant, no matter what the space in the leg of the firebox, it follows that the wider apart the two sheets are, the less bending angle will be given the bolt, and consequently the greater number of vibrations may be had before breaking. I have seen this demonstrated most conclusively in some boilers having a 7-in. water space at the crown sheet line and but 4 ins. at the mud ring, practically no broken bolts occurring above the horizontal central line of the box.

Staybolts break more frequently in bad water districts than in those districts where the water is freer from incrustating solids. This is not to be attributed to the action of the water on the bolts, but to the fact that such engines are washed out very much more frequently, with consequent vibration of the bolts each time. There is apparently no remedy for this, where water purifying stations are absent, except a flexible staybolt, and while numbers of these have been designed and tried, there are none that will not soon become inflexible through the hard scale formations around the movable parts. The best bolt therefore is one which has the greatest flexibility, and which cannot be affected by scale. Obviously this must be a solid bolt of such material that it possesses the requisite tensile strength, combined with the greatest vibratory strength. Copper undoubedly possesses this combination of qualities to a greater degree than any other metal, and it is the prevalent custom in European countries to use copper staybolts. Wih us, however, copper is seldom considered, on account of the expense.

One of the chief reasons for the superiority of copper staybolts is on account of the fibrous nature of the metal, and the more fibrous we can get a metal having the requisite tensile strength the more vibrations it will stand, and have consequently a longer life. The actual tensile strain on staybolts is far below their elastic limit, and if a bolt is not cracked it is improbable that it will ever break from boiler pressure alone. At the same time, this pressure has a great influence on the failure of staybolts, on account of the vibratory strength (to coin a new expression) being very much weakened when the vibrations take place while the bolt is under tensile strain. This point was very clearly demonstrated in tests made by Mr. Francis J. Cole, and incorporated in his paper before the American Society of Mechanical Engineers in June, 1898, and extensive tests since have established the fact beyond question. The greater the strain per square inch, then, the fewer vibrations the bolt will stand, and as a bolt of small area will have a greater strain per square inch I would recommend an area which will not give more than one-tenth ultimate strength.

Reducing the diameter of the bolt between the sheets will (within certain limits) prolong its life, the best practice being to have the turned area slightly less than the area at the root of the threads, and leaving as generous a fillet as possible.

The detection of broken staybolts is so important that no precautions should be too troublesome. The old and still used hammer test is more than unreliable, although some of our largest railways depend entirely on this means of detection. I once conducted a test of staybolt inspectors. Seven condemned boilers were used, having no drilled bolts, and each inspector went over the bolts, sounding them and marking on a prepared diagram the bolts he considered to be broken. Four of the boilers were under a steam pressure of 50 lbs. and the other three were cold. Afterwards the boilers were cut open and the actual conditions noted. Of 29 inspectors not one got all of the broken bolts in any one boiler, and no one got anywhere near the correct number of cracked bolts. Some of these men marked dozens of good bolts as "broken" and passed as many broken bolts for "good." This was the most powerful argument I ever knew against this method of inspection.

The bolt with a hole entirely through is bad on account of its weakening effect, the bolts starting to crack both from inside and out when vibrated, or exactly the same effect as when bending an ordinary piece of pipe. Of course as staybolts always break next to the outer sheet, any hole will be injurious, but by drilling a very small hole, say not over 1/8-in., just through the outer sheet, a break will be detected and the bolt injured very little by the hole, especially if a long-fiber piled iron be used. A ten minutes inspection at the end of a run will disclose any bolts which have been plugged on account of breaking on the road, and such bolts should be renewed at once. The fact that the hollow bolt cannot be plugged while on the road is to my mind an objection to it.

On account of its very short fibers, no bloom iron can possibly stand the vibrations that a piled iron will, as the latter is made up of long slim rods rolled and welded into a tough solid bar, and more nearly approaches copper in its fibrous structure. Some roads still adhere to imported bloom irons, although tests prove them far inferior to our best American piled irons when it comes to vibrations.

There are only a few of our large roads which have standard specifications for staybolt iron, and with one or two exceptions these do not include any test for vibrations. I think it true that most of the roads depend entirely on results of road tests, and rather sneer at laboratory tests as not fulfilling road conditions, and therfore valueless. Laboratory tests of staybolt iron have value, however, if for no other reason than that they give comparative results, and it is safe to assume that if we test two irons in a manner as nearly conforming to actual service as possible, the one giving the best test results will last the longest in the firebox.

A machine for testing staybolts for vibration while under tensile strain is so easily contrived that no road need be without one. Simply take an old slotting machine, and arrange a connecting arm to the tool head which will connect with a special chuck on the work-table. This special chuck is made with a stout body to be bolted to the table, and has a clamp for firmly holding the staybolt test piece. Another clamp, having a jaw to receive the connecting rod is fastened on the opposite end of the test piece, and a coil spring inserted between the two clamps with a compression nut, gives any required tension on the test piece. The stroke of the slotter is regulated to suit the vibration wished for (usually ¼-in. each side of the center line on a radius of 5 ins.) and a revolution counter will automatically count the number of double vibrations.

A slotter fixed up somewhat in this way has been in successful use in the test department at Altoona for several years, and the same arrangements could be applied to a shaping machine, so that staybolt iron could be tested in the machine shop or tool room quite as readily as in a laboratory, and we may rest assured that any iron standing say 3,000 double vibrations under a tensile strain of 2,500 lbs. will meet all other requirements as to tensile strength and elongation, besides giving the more practicable value of long life in the locomotive.

*Abstract of a paper presented at the November meeting of the Western Railway Club.
†Joseph T. Ryerson & Son, Chicago.

ANNUAL MEETING OF THE AMERICAN BOILER MANUFACTURERS' ASSOCIATION.

The fifteenth annual meeting of the American Boiler Manufacturers' Association was held at Chattanooga, Tenn., on Nov. 10-12, 1903. The meeting was devoted principally to business matters, there being no fixed program of technical discussion.

Two leading business matters were in the hands of committees during the past year, and were so continued; these are (1) the revision of the marine boiler rules of the U. S. Steamboat Inspection Service, formerly a branch of the Treasury Department, but now transferred to the new Department of Commerce and Labor; (2) the improvement of boiler tube material by reducing the permissible limit of sulphur. The first of these subjects has for two years been in charge of the standing committee on Uniform Boiler Specifications, headed by Mr. E. D. Meier. The committee has repeatedly brought this matter before the proper authorities at Washington. It soon appeared that a special legislative enactment by Congress was necessary to authorize the creation of an expert commission which should draw up revised rules for marine boilers and inspection in place of the present rules, which are said to be antiquated and not suited to present conditions. A bill for this purpose was introduced in both House and Senate at the last session, but owing to the great press of other matters the bill was not reported from the House committee. The association has enlisted the aid of other interested organizations, principally the American Society for Testing Materials and the American Steel Plate Association, and the subject has been taken up with Secretary Cortelyou, of the Department of Commerce and Labor. It is expected that action will be secured at the present session of Congress for the designation of an expert board to draw up revised rules.

The improvement of boiler tube material was the subject of negotiations, during the past year, with the American Steel Plate Association; the committee reported that these negotiations had progressed entirely favorably and that a definite agreement on the matter would probably be reached in the near future.

Several technical subjects were brought before the meeting during the second day's session for "topical discussion." Among them were: (1) Relative Merits of the Scotch Marine Boiler, the two-flue boiler, the fire-tube boiler and the water-tube boiler, for stationary service; (2) what is the best method of abating the smoke nuisance when soft coal is used as fuel; (3) in boilers for pressures over 60 lbs., should dished heads be made in one piece or in several sections. The first question, on types of stationary boilers, was referred for full discussion to the next meeting. On the question of smoke-abatement the opinion seemed to be that the various smoke-preventing methods and devices now on the market offer adequate means, but that more general enforcement of munncipal smoke laws was necessary. In discussing dished heads, the meeting expressed a preference for the one-piece head in all sizes up to the available press capacity.

Mr. D. Connelly related an air-receiver explosion which occurred recently at the plant of the Cleveland Steam Boiler Works, Cleveland, O. This receiver was 30 ins. × 22 ft., of 5-16-in. metal with ⅝-in. heads. It had formerly been used as a steam drum at 125 lbs. pressure. When put into use as an air receiver it was tested to 175 lbs. The air was supplied by a single-stage compressor giving less than 100 lbs., and an ample safety valve set at 105 lbs. was mounted on the receiver. The latter was set up on the roof-trusses about 150 ft. away from the compressor, which fed the receiver through a 4-in. pipe. The explosion occurred in the afternoon; Mr. Connelly reported that

the head split open at the manhole. The manhole was blown clear across the shop, and struck a brick wall with such force as to go half way through the wall. The pipe line leading from the receiver around the different parts of the shop was not only burst, but was opened out perfectly flat. This was small pipe, 2-in., 1½-in. and 1-in. When the explosion occurred a flame of fire shot out of the receiver and died out within a minute.

Similar explosions of air receivers and piping have been recorded in the past, and it is now well recognized that the action of the compression-heat on the lubricating oil often causes a deposit of oil and carbon in the piping which may burn, or even explode, when the accumulation is ignited from the heat of the compression or other cause. This explanation was offered at the meeting, and several other instances of explosions in air systems were reported.

The social side of the meeting was taken care of by excursions to Lookout Mountain and Chickamauga, a sociable, with cakewalk, etc.

St. Louis was selected as the place for the next annual meeting, the date is to be fixed later. The officers elected for the coming year are: President, Mr. J. O'Brien, of St. Louis, Mo.; Vice-Presidents, Messrs. R. Munroe, Jr., of Pittsburg, Pa.; M. F. Cole, of Newnan, Ga.; J. S. Casey, of Chattanooga, Tenn.; P. J. Hamler, of Chicago, Ill.; and P. H. Dundon, of San Francisco, Cal.; Secretary, Mr. J. D. Farasey, of Cleveland, O.; Treasurer, Mr. J. F. Wangler, of St. Louis, Mo.

FIG. 119. VIEW SHOWING CUT AND CONCRETE ARCH SUBWAY.

THE NEW YORK RAPID TRANSIT RAILWAY. XXIV.

Contract Section IX-b.

Contract Section IX-b. of the New York Rapid Transit Railway extends from the center line of Gerard Ave. to the west building line of Brooke Ave. and Westchester Ave., and is wholly in the Borough of Bronx. The subcontractor for the construction of the section was Mr. John C. Rodgers.

SUBWAY STRUCTURE.—The subway structure of Section IX-b. includes standard steel beam and concrete subway, concrete-lined tunnel and reinforced concrete subway. Starting from Girard Ave., the ground rises rather abruptly to a summit at Mott Ave., then drops gradually to a valley at Morris Ave. There is then a gradual rise to Courtlandt Ave., forming a second ridge or hill, which slopes down to the terminus of the section. From Girard Ave. through the first hill the subway structure is three-centered concrete arch of the dimensions shown by Fig. 118. Fig. 119 is a view looking south and showing a small piece of this tunnel completed north from Girard Ave. By reference to Fig. 118 it will be observed that the concrete arch section is of the same type as that forming the shore portions of the Harlem River tunnel. Directly under Mott Ave. this section is widened out into a three-centered arch of 50-ft. span, to provide for the Mott Ave. station. Fig. 120 shows the details of this station arch. The total length of the concrete arch work is about 1,560 ft., then follows 1,000 ft. of steel beam and concrete subway, then a short length, about 540 ft., of concrete arch, through the second hill, and then reinforced concrete subway to the end of the section. At certain points special constructions were employed, and are described briefly in a succeeding paragraph.

MATERIALS PENETRATED.—At Girard Ave. the subsoil is loose and sandy and carries considerable water, but this soon changes to mica schist rock, as shown by Fig. 119, which forms the hill on which is Mott Ave. The line runs out of this rock on the north side of the hill, and continues in loose soil throughout the remainder of the section.

STREET AND ADJACENT STRUCTURES.—At two points on Section IX.-b. straightforward construction was interfered with by existing structures. The first of these interfering structures was the roadbed and tracks of the New York Central & Hudson River R. R., and the highway bridge which carries 149th St. over these tracks. The subway had to be carried under these structures while supporting them in place with no disturbance to traffic. The second structure to require special consideration was the sewer crossing the subway at nearly the same point as the railway tracks. This was replaced by the siphon described in the preceding article on Sewer Diversion.

SPECIAL CONSTRUCTION.—At two points on the section a special construction had to be employed. As shown by Fig. 121, the subway cuts under the two abutments of the 149th St. bridge over the eight tracks of the New York Central & Hudson River R. R. Here an especially heavy construction was necessary, and each bent of the subway consists of a sill made up of two 12-in. I-beams with separators, two 15-in. I-beam wall columns and a roof beam 2 ft. deep. Near the end of the section a very shallow roof plate was necessary to keep below the surface, and here the following construction was adopted: The tops of the center columns were connected along the tunnel by means of 12-in. I-beams. To this center beam the tops of the wall columns were connected by 9-in. I-beams, and between these beams there were inserted other 9-in. beams attached to the center beam at one end and resting on the side walls at the other end. There were three of these intermediate beams in each bay, the spacing of the roof beams being thus 15 ins. apart.

METHODS OF WORK.—The methods of work employed on Section IX-b. do not call for extended description. A single wide track was opened throughout the section and in this was built the subway structure. To remove the earth from the trenches cableways were employed and dumped the spoil into wagons, which carried it to low lying ground, where it was used as filling. For the concrete arch work sidewall forms and centers were employed in the usual manner, and the concrete was mixed for the most part by hand.

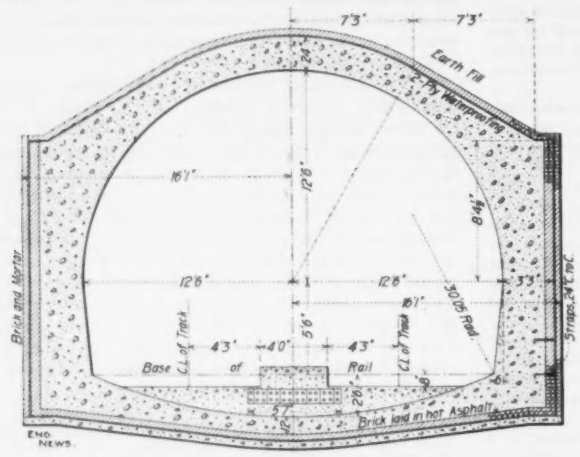


FIG. 118. CROSS-SECTION OF CONCRETE ARCH SUBWAY IN DEEP CUT.

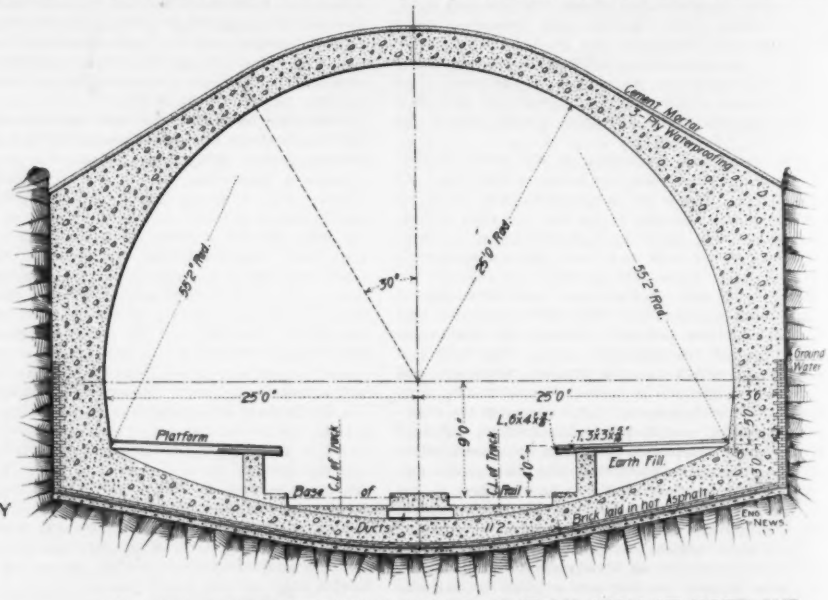


FIG. 120. CROSS-SECTION OF 50-FT. STATION ARCH AT MOTT AVE.

PERMISSIBLE WHEEL-LOAD PER FOOT OF WHEEL-DIAMETER AND PER INCH OF BREATH OF RAIL-HEAD.*

By Francis J. E. Spring,† C.I.E., M. Inst. C. E.

The rule now in force for Indian railways fixes the axle-load per foot of wheel-diameter separately for the two gages, viz., 3.75 tons‡ for the 5-ft. 6-in. gage, and 3 tons for the meter-gage; being equivalent to 350 lbs. and 280 lbs. respectively, per wheel, per inch of wheel-diameter. The only reason the author can assign for this differentiation between the gages is that it has all along been recognized that wear and tear depend not merely on the load, but also on the area of the mutually abraded surfaces, of which the breadth of the rail-head is an element. The permissible axle-load of 3.75 tons per foot of wheel

*From the "Proceedings of the Institution of Civil Engineers."

†Consulting Engineer for Railways, Madras, India.

‡It should be noted that the ton used by the author in this paper is the English long ton of 2,240 lbs.

diameter is liable to run on rails having heads varying in breadth between 1.75 and 2.33 ins., while the corresponding 3-ton load is liable to run on rails varying between 1.25 and 1.66 ins., in breadth of head.

The author proposes to apply the term "Index Number" to "wheel-load in pounds per inch of wheel-diameter, per inch width of moderately worn rail-head." In India the Index Number, which the author claims to be the proper measure for abrasion, varies between 224 for the narrowest meter-gage rail and 107 for the widest broad-gage rail in use on the railways. If the 75-lb. rail, with a head 2 ins. in breadth when worn down 1-10-in. at the center, be taken as the standard for rails on which freight cars having wheel-loads of 350 lbs. per in. diameter run; and if the 50-lb. rail, with a head 1.66-in. in breadth when worn down 1-10-in. at the center, be taken as the standard for wheel-loads of 280 lbs. per in. diameter, Indian Index Numbers 150 for standard gage and 155 for meter gage are obtained. The next point for consideration is whether these are habitually exceeded or not, on large railway systems elsewhere, where this particular question of railroad economics appears to receive the attention that it deserves.

Decision as to a maximum wheel-load for wagon stock is influenced by the consideration that, when a certain wheel-load per inch of wheel-diameter is reached, the economy that results from increased loading or the convenience that results from a smaller wheel, is counterbalanced by the wear of the surfaces of the rail and wheel, as well as by the wholesale scrapping of rails not fit to be left in the road. One-quarter inch of wear off the top of an Indian 75-lb. rail means a loss of weight of

FIG. 121. VIEW SHOWING PASSAGE OF SUBWAY UNDER 149TH ST. BRIDGE AND NEW YORK CENTRAL RAILROAD.

about 6 lbs. per yd., and doubtless the equivalent of another 6 lbs. per yd. of rail off the wheels which have been responsible for the wear. This amounts to 943 tons (representing 100,000 to 150,000 rupees), for 100 miles of railway, for loss of steel alone. The railway economist must compare this loss, and the approaching scrapping of the rails, with the gain from heavier wheel-loads; for rails calculated for certain loads cannot, considered as girders, safely go on carrying those loads when their weight is reduced by more than 8 or 10%.

The question, then, for the economist is: How many years is it permissible to allow before scrapping rails, such scrapping being the price paid for the saving in working expenses which results from increased wheel-loads? Needless to say, with the available data, the problem is not soluble on theoretical considerations. All that can be done is to judge in a general way whether existing wheel-loads are so light as probably to give too long a life to the rails. Guidance in regard to this can be obtained from experience in England, America and elsewhere. If well-managed roads are found where higher wheel-loads are tolerated than in India, it may safely be concluded that the managers of these roads are satisfied that it pays, for the sake of higher loads, to scrap their rails somewhat earlier. It is conceivable that for the sake of better loads it might pay to scrap rails wholesale in 10 years instead of in 20 years; or, after so many million tons had passed over them, instead of double that number; or after so many heavy wheel-loads had rolled past, instead of double the number of light wheel-loads; or after some agreed percentage of weight from wear and tear, and corrosion, had been lost. The author does not propose, however, to investigate the whole question, the available data being inadequate. Some valuable data are contained in Mr. P. H. Dudley's Report of the Sixth Session of the International Railway Congress, 1900, but even these are inadequate for the satisfactory solution of so complicated a problem. The author proposes, therefore, simply to endeavor to ascertain how the load may vary with the wheel-diameter and with the breadth of the rail-head.

A newly turned wheel can be in contact with a newly rolled rail only over a very restricted area, because the wheel and the rail-head are both parts of cylinders, and the theoretical contact of two cylinders is a point. After some time, when the rail gets worn down, the surface of the rail-head becomes a plane, and the wheel still remains a cylinder (or a truncated cone), so that the contact between the two takes place no longer at a point, but on a line. Both the wheel and the rail-head being elastic, there is mutual yielding at the point or along the line of contact, so that the point becomes a more or less circular area, and the line a more or less irregular parallelogram. When the load is increased, the area extends until the load is balanced by the total resistance of the compressed elastic metal over the whole contact-surface. In the long run, the amount of wear and tear of the tire and rail-head will depend chiefly on the intensity of stress which is permitted to occur in the worst-stressed fibers of the contact-area. A traffic of 100 trains (say, 4,000 wheels) per day gives, say 15 million compressions to the rail-top in ten years. If these 15,000,000 compressions are of such intensity that the stress in the worst-treated fiber exceeds the elastic limit, there necessarily will be flow or disruption of the rail-head; and even if the stress be comparatively moderate, there necessarily must be wear and tear of the mutually-abrading surfaces of the wheel and rail. For similar wheel-loads and similar rails, intensity of stress is a function of wheel-diameter, since the length (along the rail) of the small compression-area is clearly proportional to the wheel-diameter.

A rail with a small radius of head, say, 5 ins., such as the Indian 62-lb. or 80-lb. rail, or 5½ ins., like the 4¼-lb. rail, sustains at first great wear and tear, because the wheel-loads produce an extremely large intensity of stress on the small contact-surface. This in time cures itself, and after a rapid initial wearing down, and probably also flow, at the center of the rail-head, the radius may increase to any extent, even to infinity, which gives a flat head. The better-designed rails have larger head-radii; thus the 50-lb. meter-gage rail has a radius of 15 ins., and the 100-lb. 5-ft. 6-in. gage rail has a radius of 12 ins. Even these wear down in time to more or less a straight line on the rail-section. The object is that, after the first few years of roughing down, the ratio of wheel-load to contact-area shall be such as to allow of the rail being retained in use for that period which has been decided to be its economical life, as conditioned by the traffic economy which follows the use of heavier wheel-loads. These considerations lead the author to put forward the following as a fair ordinary type of design of rail-head. He does not specify radius of head, considering that this must to some extent depend on the technics of rolling mills. What is aimed at is a rough rule giving breadth of wheel-tread after moderate average wear and tear:

"When 1-10-in. shall have been worn off the summit of the rail-head, the breadth of the worn top shall be, in inches:

1 + 1⅓ × weight of rail in hundred pounds per yard;
or,
1 + four times the weight of the rail in hundred pounds per foot."

This accords with good existing Indian practice for rails weighing between 50 lbs. and 100 lbs. per yard.

Considerable light is thrown on this important branch of railway economics by two papers read before the American Society of Civil Engineers, and the discussions thereon, namely: (1) "Destruction of Rails by Excessive Weights," by Mr. Joseph T. Dodge,* and (2) "Cylindrical Whels and Flat-Topped Rails for Railways," by Mr. D. J. Whittemore.† From these very instructive papers the following is extracted as being likely to aid in arriving at a suitable expression for axle-load per foot of diameter of wheel to suit various rails.

Mr. Dodge in discussing the observed bulging out, or flow, of rail-heads, and ascribing it to the excessive intensity of load per unit of contact-area when rails having a small top-radius are used, observed that bearing-areas vary with the radii of the wheels and with the width of the rail-heads. He mentions an eight-wheel freight-car weighing 25,000 lbs., and carrying 41,000 lbs., as being as destructive of rails as a consolidation engine carrying 96,000 lbs. on its eight driving wheels, of 4-ft. diameter. Presumably, the car wheel was the American standard 33-in. wheel, and in this case the axle-load would be only 7.36 English tons, or 2.68 tons per foot diameter. The axle-load of the engine would be 10.71 tons, or 2.68 tons per foot diameter. These are certainly not high. In the discussion on Mr. Dodge's paper, Mr. W. W. Rich mentioned a car weighing 27,000 lbs., and carrying 50,000 lbs. on eight 33-in. wheels. This would give an axle-load of 8.14 tons, or 3.12 tons per foot diameter. These two are not even as high as the highest permissible Indian loads, which are 3.75 tons and 3.00 tons for 5-ft. 6-in. gage and meter gage, respectively, i.e., for use on rails 1.75 ins. to 2.25 ins., and 1.25 ins. to 1.50 ins. in breadth, respectively. The American figures are, however, 13 years old. Mr. Rich's reference to the latter car was in connection with observed contact-areas of 1-10 sq. in. to 1-11 sq. in. between wheel and rail; this means a stress of 100,000 lbs. per sq. in., which would at once account for flow. He mentions a switch engine with 16,000 lbs. on a 32-in. wheel, which means an axle-load of 14.28 tons, or 3.31 tons per ft. diameter, as "leaving its record about the yard in some good-sized splinters rolled from the rail-heads." In the same discussion Mr. Thomas Rodd spoke of 12-wheel cars weighing 120,000 lbs. gross. This would give an axle-load of about 9 tons, or 3.25 tons per foot diameter of wheel. It is evident that American practice of 13 years ago was behind present Indian practice in the matter of relationship of load to wheel-diameter. It came out incidentally in the discussion on Mr. Dodge's paper, that it was not at that time the practice in America to cant rails with a view to bringing their top surface into approximate coincidence with coned car-wheel treads. This has invariably been done in India for the last 30 or 40 years.

From that splendid summary of American practice in respect to wheels and rails, already referred to, namely, Mr. P. H. Dudley's report, it appears that the axle-loads commonly employed in the United States are:

For freight cars of 60,000 lbs. capacity, 23,000 lbs. per axle for 33-in. wheels;
For freight cars of 80,000 lbs. capacity, 27,800 lbs. per axle for 33-in. whels;
For freight cars of 100,000 lbs. capacity, 35,000 lbs. per axle for 33-in. wheels.

So far as the author has been able to ascertain, the rails on which these highly concentrated loads are run vary between 80 lbs. and 100 lbs. per yard, with heads which, when a little worn, vary in breedth between 2.08 ins. and 2.60 ins. Their Index Numbers can therefore be calculated, and are given in the following table:

Load per axle, lbs.	23,000	27,800	35,000
Load per wheel, lbs.	11,500	13,900	17,500
Load per in. of wheel diameter, lbs	348	421	530
Breadth of worn rail-head, ins.	2.08	2.34	2.60
Index Number	167	180	204

If, however, the heaviest load runs on the 80-lb. rail the Index Number will be 255. The author thinks it probable that 200 may be taken as a fair Index Number for American approved practice, on roads where due care is devoted to proper co-ordination between the operating economy due to heavier loads and the wear and tear involved in the use of such loads. He therefore inclines to the opinion that an Index Number of 200 might well be adopted for India. The Index Number in India at present is not far from 155.

The author has recently been called upon to advise on this important question of practical railway economics, owing to the fact that, quite recently, the London consulting engineer to an Indian railway company prepared a design for a goods-wagon of 70,560 lbs. gross weight on eight 33-in. wheels, which he was prepared to use at first for gross weights of 52,720 lbs. These give axle-loads of 17,640 lbs. and 13,180 lbs. or 534 lbs. and 400 lbs. per in. of wheel-diameter. The loads and wheel-

*"Transactions American Society of Civil Engineers," Vol. XX., p. 121.
†"Ibid," Vol. XXI., p. 133.

diameter proposed give an Index Number of 134 for the 85-lb. rail of one section of the line, and of 144 for the 75-lb. rail of another section. It is obvious, therefore, that, so far as wheel-diameter is concerned, the destructive effect of the proposed wheel and wheel-load will be far less than what is accepted as economically permissible in American practice, and less even than what is admitted at present to be perfectly permissible in Indian practice. The author, therefore, was able to advise that he saw no objection to sanctioning the use of 33-in. wheels on 75-lb. to 85-lb. rails, for 31½-ton gross loads on eight wheels.

In conclusion, the recommendations contained in these notes may be summarized as follows:

(a) Rail-heads should be so designed that when 1-10-in. shall have been worn off the summit of the rail-head, the breadth of the worn top shall be, in inches:

$1 + 1\frac{1}{3} \times$ weight of rail in hundred pounds per yard;

or,

$1 + 4 \times$ weight of rail in hundred pounds per foot.

(b) That, for India, the Index Number, for proportioning wheel-load to diameter of wheel and breadth of rail-head—that is, pounds of load per wheel, per inch of wheel diameter, per inch of rail-head—as per recommendation (a)—shall be 200.

If these recommendations be accepted for Indian practice, the permissible axle-load per foot of wheel-diameter may be 4.286 tons for 5-ft. 6-in. gage 75-lb. rails, and 3.571 tons for meter gage 50-lb. rails. For roads on which 100-lb. rails may be used, the permissible axle-load per foot of wheel-diameter may be 5 tons. These revised loads would take the place, if accepted, of the present 3.75 tons for the 5-ft. 6-in. gage, and 3.00 tons for the meter gage, per foot of wheel-diameter, irrespective of breadth of rail-head.

STATISTICS OF RAILWAYS IN THE UNITED STATES IN 1903.

From advance sheets of the 30th annual issue of Poor's Manual of Railroads we are able to present some interesting statistics of United States railways in the last fiscal year.

The total mileage of railways completed up to Dec. 31, 1902, was 203,131 miles, of which the traffic and financial statistics are given in the "Manual" for 197,438 miles. The record of traffic for the fiscal year 1902 is as follows:

Passengers carried	655,130,236
Passengers, mileage	19,706,908,785
Tons freight moved	1,192,136,510
Tons freight moved, 1 mile	156,624,166,024

The financial results of the operation are summarized as follows:

Earnings:	
Passenger	$396,513,412
Freight	1,197,212,452
Other	115,715,822
Of switching and belt R. Rs.	11,373,214
Total traffic revenue	$1,720,814,900
Operating expenses	1,100,788,623
Net earnings	$560,026,277
Other receipts	77,663,483
Total available revenue	$637,689,760
Payments from available revenue:	
Interest on bonds	$222,614,900
Other interest	9,733,560
Dividends	151,046,537
Rentals—Interest	$40,622,542
Dividends	27,154,215
Miscellaneous	19,970,212— 87,746,969
Miscellaneous	57,408,351
Total	$528,523,326
Balance.—Surplus over fixed charges and miscellaneous payments	$109,166,434

This is by far the greatest financial return, both gross and net, ever made by the railways of the United States. Not only are the totals larger, but the earnings per mile have increased. Table I., reproduced herewith, shows that the average earnings per mile of United States railway last year were $8,696, while the net earnings were $2,830. It will be seen that the rate of earnings per mile, both gross and net, reached a high point in 1883, just before the great boom in railway construction, which culminated in 1887. The average was rapidly brought down by the mileage of new lines of comparatively thin traffic, and not till 1901 did the average net earnings per mile equal what they were in 1883.

Tables II. and III. furnish data of much historical interest with reference to the progress of railway construction and the growth of railway traffic as indicated by increase in rolling stock. It will be seen that the number of freight cars has increased 50% in the past 14 years. This does not tell the whole story of traffic increase, however, for at the same time the capacity of freight cars has been greatly increased; so much so that one might judge the freight traffic to have fully doubled in the past 14 years. Reference to Table V. shows this to be actually the case. The table gives the figures for 13 years only, or to 1890, but allowing an equal rate of increase from 1889 to 1890 to what actually occurred the following year we have a freight traffic of 77 billion ton-miles in 1889 and of 156 billion ton-miles in 1902. Pas-

TABLE I.—Railroad Capitalization and Earnings from 1883 to 1902.

	Interest, Average Rate.	Dividends, Average Rate.	Per Ton per Mile, Average Rate.	Per Passenger per Mile, Average Rate.	Earnings per Mile of R.R. in Operation. Gross.	Net.	Per cent of Net to Gross.
	p. c.	p. c.	Cents.	Cents.	$	$	
1883	4.94	3.76	1.224	2.422	7,665	2,979	38.9
1884	4.97	3.69	1.118	2.356	6,983	2,318	33.2
1885	4.97	3.03	1.037	2.199	6,370	2,163	34.0
1886	4.98	2.69	1.042	2.124	6,570	2,376	36.2
1887	4.96	2.17	1.024	2.076	6,798	2,416	35.5
1888	4.48	1.80	0.977	2.046	6,540	2,045	31.3
1889	4.57	1.79	0.970	2.109	6,440	2,080	32.3
1890	4.44	1.82	0.927	2.174	6,675	2,166	32.4
1891	4.41	1.87	0.929	2.164	6,661	2,135	32.1
1892	4.36	1.91	0.941	2.189	6,652	2,096	31.5
1893	4.31	1.88	0.893	2.073	6,063	2,060	34.0
1894	4.19	1.66	0.864	2.054	5,663	1,903	33.6
1895	4.24	1.58	0.859	2.089	5,997	1,904	31.8
1896	4.43	1.52	0.831	2.228	6,333	1,845	29.1
1897	4.34	1.49	0.797	2.266	6,275	1,864	29.7
1898	4.21	1.66	0.753	1.884	6,771	2,111	31.2
1899	4.24	1.84	0.779	2.005	7,161	2,272	31.7
1900	4.24	2.42	0.749	2.031	7,828	2,519	32.2
1901	4.21	2.61	0.756	2.028	8,370	2,666	31.9
1902	4.07	2.93	0.784	2.013	8,696	2,830	32.5

senger traffic, however, shows a very much smaller rate of increase, or from 12 billion passenger-miles in 1890 to 19 billion in 1902. Of course, part of this slower rate of increase of passenger traffic is explained by the suburban traffic which has been taken by electric railways.

The figures of steel and iron rails are of much interest to engineers. Since 1880 the mileage of iron rails has been steadily decreasing, although at a very irregular rate. From 1880 to 1881, from 1885 to 1886, and in the years 1890-'92 and 1895-'96 comparatively few iron rails were taken up. The remarkable thing is that there are still over 17,000 miles of iron rails in service somewhere. They must have been rolled for the most part at least 20 years ago, and many of them are doubtless much older. A large part are doubtless on little-used sidings; but that they should remain in use at all at the present day is a fact worthy of note, as illustrating how long even the poorest and worst rails may last under light traffic.

The "Manual" itself, of which these statistical tables form the introduction, has grown in bulk this year by 150 pages. We shall present a further review of its contents in our next Engineering Literature Supplement.

TABLE II.—Statistics of Track Mileage and Rolling Stock Equipment of United States Railways, 1880 to 1902.

Year.	Miles Steel Rails.	Miles Iron Rails.	Total Track (Miles.)	Per Cent. Steel of Total.	Locomotives.	Revenue Cars			
						Passenger.	Baggage, Mail and Express.	Freight.	Total.
1880	33,680	81,967	115,647	29.1	17,949	12,789	4,788	539,255	556,930
1881	48,984	81,471	130,455	37.5	19,911	13,947	4,976	648,295	667,218
1882	66,611	74,267	140,878	47.3	21,889	14,934	5,584	730,435	750,933
1883	87,490	70,690	149,101	52.6	23,405	15,230	5,848	778,663	800,741
1884	90,162	66,252	156,414	57.6	24,353	16,644	5,911	796,399	820,954
1885	98,013	62,493	160,506	61.0	25,662	16,497	6,044	805,517	828,058
1886	105,630	62,322	167,952	62.9	26,108	18,365	6,325	845,912	870,602
1887	125,349	59,586	184,935	67.8	27,275	19,339	6,554	950,889	976,772
1888	138,395	52,981	191,376	72.3	29,006	20,247	6,827	1,005,108	1,032,182
1889	151,578	50,510	202,088	75.0	30,566	21,471	7,053	1,051,141	1,080,665
1890	167,458	40,694	208,152	80.4	31,812	21,664	7,253	1,061,952	1,090,869
1891	174,775	39,754	214,529	81.5	33,563	23,083	7,388	1,163,679	1,194,130
1892	182,711	38,918	221,629	82.4	34,626	24,604	7,830	1,177,113	1,209,457
1893	190,718	37,135	227,853	83.7	36,118	27,179	7,877	1,206,444	1,241,500
1894	197,491	35,264	232,755	84.9	36,304	26,357	7,921	1,228,781	1,263,059
1895	206,381	28,650	235,031	87.8	36,610	26,419	7,891	1,230,798	1,265,108
1896	210,290	28,440	238,730	88.1	36,388	24,940	7,880	1,245,640	1,278,460
1897	215,658	26,043	241,701	89.2	36,410	25,854	8,180	1,234,972	1,268,806
1898	220,804	24,435	245,239	90.0	36,746	25,844	8,049	1,284,807	1,318,700
1899	228,976	21,387	250,363	91.5	37,245	26,184	8,121	1,328,084	1,362,389
1900	238,464	19,389	257,853	92.4	38,065	26,786	8,209	1,350,258	1,385,253
1901	246,811	19,181	265,992	92.7	39,729	27,144	8,667	1,409,472	1,445,283
1902	257,437	17,398	274,835	93.6	41,626	27,364	9,726	1,503,949	1,541,039

TABLE III.—Railway Construction in the United States from 1830 to the Close of 1902.

Year.	Miles in Operation.	Annual Increase of Mileage.	Year.	Miles in Operation.	Annual Increase of Mileage.	Year.	Miles in Operation.	Annual Increase of Mileage.
1830	23	.....	1855	18,374	1,654	1880	93,262	6,706
1831	95	72	1856	22,016	3,642	1881	103,108	9,846
1832	229	134	1857	24,503	2,487	1882	114,677	11,569
1833	380	151	1858	26,968	2,465	1883	121,422	6,745
1834	633	253	1859	28,789	1,821	1884	125,345	3,923
1835	1,098	465	1860	30,626	1,837	1885	128,320	2,975
1836	1,273	175	1861	31,286	660	1886	136,338	8,018
1837	1,497	224	1862	32,120	834	1887	149,214	12,876
1838	1,913	416	1863	33,170	1,050	1888	156,114	6,900
1839	2,302	389	1864	33,908	738	1889	161,276	5,162
1840	2,818	516	1865	35,085	1,177	1890	166,654	5,378
1841	3,535	717	1866	36,801	1,716	1891	170,729	4,075
1842	4,026	491	1867	39,250	2,249	1892	175,170	4,441
1843	4,185	159	1868	42,229	2,979	1893	177,516	2,346
1844	4,377	192	1869	46,844	4,615	1894	179,415	1,899
1845	4,633	256	1870	52,922	6,078	1895	181,065	1,650
1846	4,930	297	1871	60,293	7,379	1896	182,769	1,704
1847	5,598	668	1872	66,171	5,878	1897	184,591	1,822
1848	5,996	398	1873	70,266	4,097	1898	186,810	2,219
1849	7,365	1,369	1874	72,385	2,117	1899	190,818	4,008
1850	9,021	1,656	1875	74,096	1,711	1900	194,334	3,516
1851	10,982	1,961	1876	76,808	2,712	1901	198,768	4,434
1852	12,908	1,926	1877	79,082	2,274	1902	203,132	4,365
1853	15,360	2,452	1878	81,747	2,665			
1854	16,720	1,360	1879	86,556	4,809			

TABLES IV. AND V.—Statistics of Passenger and Freight Traffic of United States Railways, 1890 to 1902.

TABLE IV.—Passenger Traffic.

Years.	Length of RRs. in Operation.	Miles Run by Passenger Trains.	Passenger Traffic.		Passenger Earnings				Aver. No. of Passengers per Mile of Railroad.	Aver. No. of Passenger Miles per Pass. Train Mile.	Average Distance Traveled p. Passenger.
			Pass'ng'rs Carried.	Passenger Movement.	Gross Amount.	Av. Receipts p. Pass. p. Mile.	Av. Rec. per Pass.	Av. Rec. p. Pass. Train Mile.	Av. Rec. p. Mile of RR.		
	Miles.	Miles.	No.	Miles.	$	Cents.	Cents.	Cents.	$	No.	Miles.	Miles.
1890	157,976	297,244,707	520,439,082	12,521,565,649	272,320,961	2.174	52.13	91.61	1,724	3,294	42.12	24.05
1891	164,262	320,712,013	556,015,802	13,316,925,239	290,799,696	2.184	52.30	90.67	1,770	3,385	41.52	23.95
1892	170,607	323,930,550	575,769,678	13,584,343,804	293,557,476	2.168	50.99	90.62	1,721	3,375	41.93	23.59
1893	173,301	338,551,606	597,056,530	14,979,847,458	310,442,870	2.072	52.00	91.70	1,791	3,444	44.23	25.09
1894	176,221	325,981,809	569,660,216	13,600,531,635	275,352,190	2.025	48.34	84.47	1,563	3,233	41.72	23.67
1895	179,154	326,184,596	529,756,259	12,609,082,551	260,929,741	2.069	49.25	79.99	1,456	2,957	38.66	23.88
1896	180,891	337,641,115	535,120,756	13,054,840,243	265,313,258	2.032	49.58	78.58	1,467	2,958	38.66	24.40
1897	180,621	342,464,408	504,106,205	12,494,958,000	253,537,936	2.029	50.30	74.04	1,403	2,791	36.46	24.78
1898	183,216	344,761,142	514,982,888	13,672,497,664	272,589,591	1.994	52.93	79.07	1,488	2,811	39.66	26.55
1899	185,550	355,106,833	537,977,301	14,859,541,965	297,559,712	2.002	55.31	83.79	1,604	2,899	41.84	27.63
1900	190,694	373,226,581	584,695,935	16,313,284,471	331,402,816	2.031	56.67	88.79	1,738	3,066	43.22	27.90
1901	193,823	391,543,708	600,485,790	17,789,669,925	360,702,686	2.028	60.07	92.12	1,861	3,098	45.43	29.63
1902	196,648	403,213,178	655,130,236	19,706,908,785	396,513,412	2.012	60.52	98.34	2,016	3,331	48.87	30.08

TABLE V.—Freight Traffic.

Years	Length of RRs. in Operation.	Miles Run by Freight Trains.	Freight Traffic.		Freight Earnings.					Aver. No. of Tons per Mile of Railroad.	Aver. No. of Tons Miles per Freight Train Mile.	Average Haul per Ton.
			Freight Carried.	Freight Movement.	Gross Amount.	Av. Receipts p. Ton p. Mile.	Ave. Rec. per Ton.	Av. Re. p. Fre't Train Mile.	Av. Re. per Mile of RR.			
	Miles.	Miles.	Tons.	Miles.	$	Cents.	Cents.	Cents.	$	Tons.	Miles.	Miles.
1890	157,976	482,900,422	691,344,437	79,192,985,125	734,821,733	0.927	106.28	152.17	4,651	4,376	163.99	114.55
1891	164,262	493,541,969	704,398,609	81,210,154,523	754,185,910	0.929	107.07	152.81	4,591	4,288	164.55	115.29
1892	170,607	523,831,458	730,606,011	84,413,197,130	794,526,500	0.941	108.74	151.67	4,657	4,282	161.14	115.53
1893	173,301	531,340,734	757,464,490	90,552,067,290	808,494,668	0.893	106.74	152.16	4,663	4,369	170.42	119.55
1894	176,221	475,780,885	674,714,747	82,219,900,498	709,477,409	0.864	103.50	147.22	3,975	3,829	172.81	121.86
1895	179,154	491,410,820	755,799,883	88,567,770,801	743,784,451	0.839	97.38	151.36	4,151	4,263	180.23	115.96
1896	180,891	497,248,296	773,868,716	93,885,853,634	770,424,013	0.821	99.55	154.94	4,259	4,278	188.81	121.32
1897	181,065	500,326,372	788,385,448	97,842,569,150	780,351,936	0.797	98.99	157.77	4,310	4,354	195.56	124.22
1898	184,117	542,824,503	912,973,833	114,566,173,191	868,924,526	0.758	95.18	160.09	4,719	4,959	211.06	125.50
1899	186,224	534,391,846	975,789,941	126,901,703,110	922,436,314	0.726	94.53	172.61	4,953	5,240	237.64	130.04
1900	191,455	513,667,388	1,071,431,919	141,162,109,413	1,052,835,611	0.746	98.30	204.95	5,499	5,596	274.79	131.80
1901	194,455	505,468,619	1,064,066,451	148,950,303,492	1,126,267,652	0.756	103.89	222.82	5,792	5,575	294.70	137.41
1902	197,381	506,210,140	1,192,136,510	156,624,166,024	1,197,212,452	0.764	100.43	235.57	6,065	6,041	308.19	131.38

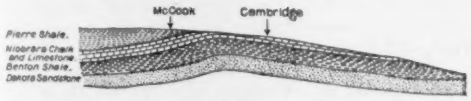
AN IMPORTANT UPLIFT UNDER THE GREAT PLAINS.

In investigating the geological structure of the Central Great Plains region, Mr. N. H. Darton, of the United States Geological Survey, has discovered an uplift, or arch, in the earth's crust, which may have great economic importance. Owing to the thick covering of clays and sands in the Plains, the structure of the underlying rocks is difficult to ascertain, but, from a careful survey of exposures in Western Kansas, the Republican Valley in Nebraska, and the southwestern corner of South Dakota, and a consideration of much new evidence afforded by well borings in the last few years, Mr. Darton has demonstrated the existence of a narrow arch of considerable magnitude, extending from the vicinity of Lenora, Kan., through Norton county, across Furnace, Frontier, Lincoln and other counties in Nebraska to the White River, where this river crosses the Nebraska-South Dakota state line.

Map Showing Location of the Great Plains Anticline.

This uplift is probably due to a slight shrinkage of the earth's crust, and an extensive series of cretaceous and underlying rocks are involved. As oil and gas are often associated with uplifts of this character, the one above noted will undoubtedly attract the attention of those who are seeking for these products. Two deep wells, now in progress at Jennings and Kanona, Kan., lie slightly west of the line of uplift, so that they will not fully test its capabilities.

A report now in preparation on the geology of the Great Plains, by Mr. Darton, will be issued by the Geological Survey in the course of a few months, and describe more fully the geological structure and resources in the region.



Geologic Section of Great Plains Anticline.

THE RAILWAY TIE QUESTION.

In a review of the railway tie situation, published in our issue of Sept. 10, attention was called to the serious difficulties now confronting the railways in regard to the supply of and the economical use of railway ties. At the recent annual convention of the Roadmasters' and Maintenance-of-Way Association, in Kansas City, the tie question received more time and attention than any other subject. There were two reports presented dealing with this question, and it was also dealt with in an address delivered by a representative of the forestry division of the Department of Agriculture. There was also a long and brisk discussion upon various phases of the question. A general report of the proceedings was given in our issue of Oct. 22, and we give herewith abstracts of the reports, the address, and the discussion above referred to:

REPORT OF THE COMMITTEE ON TIES.

The future supply of timber for railway ties, the conservation of this supply, and the substitution of materials other than wood for this purpose, are questions to which railway managements will soon have to devote serious study, and which are already being considered by some roads. The great demand upon the forests in the past and present, and the destruction of large quantities of timber by fire each year, have fast been cutting off the reserve of timber in this country, and consequently the price of timber for all construction purposes is steadily increasing. In fact, at the present rate of consumption and destruction of timber, it is estimated that the supply will be practically exhausted in 30 or 40 years from now. It is known that the vast requirements of railway companies for ties to meet yearly renewals and for construction of new track, cannot long be supplied from domestic sources if the present demand and consumption continue, and it is evident that some measures must be taken to reduce the demand, or increase the life of ties.

TIE PLATES.—We regard metal tie plates as an important improvement, for they protect the timber from rail cutting and enable the ties to remain in service in the track during their natural life, or until rendered worthless by decay, except when they are injured by the spikes. This spike-killing, however, can only be entirely prevented by the use of some improved fastening, which has not yet been introduced.

PRESERVATIVE TREATMENT OF TIES.—On this subject, and the seasoning of timber, extensive experiments are being conducted by several railways and under the direction of the United States Department of Agriculture, and there is now a very extensive use of treated ties in this country. The preservation of railway ties by the injection of chemicals is now long past the experimental stage.

The zinc-chloride process is the one in general use in this country (with or without a secondary treatment). A systematic and extensive use of ties thus treated is within the experience of at least three large railway systems of this country for the past 16 years, and with several other railways for shorter although satisfactory periods. The Atchison, Topeka & Santa Fe Ry. began the use of treated ties early in 1885, and has laid treated ties in large numbers every year since that date. The experience of this road has shown that with mountain pine ties, the natural life of which is only four or five years in New Mexico and Arizona, the average life has been increased, by treating with zinc-chloride, to over 11 years for seven divisions of the road, and to 12 years on the Rio Grande division; or from 2½ to 3 times the life of the untreated tie. The experience of the Southern Pacific Ry. since 1887 has been likewise satisfactory. On the Chicago, Rock Island & Pacific Ry. treated hemlock ties have been in use since 1887, with satisfactory results, and the records show that the life of the natural timber has been increased two to three times by chemical treatment.

The work that is being done in rendering soft, cheap, and otherwise unserviceable woods fit for use as ties, we regard as very important and promising, and one that is effecting great economy in the use of railway ties in this country.

Thus far the most satisfactory material, cost being considered, that has been used for the chemical treatment of ties in this country is zinc-chloride, a cheap salt that is readily soluble in water; this being the medium by which it is injected into the timber. The strength of the solution is generally 1.6 to 2% of pure chloride salt; but stronger solutions are sometimes used. In the Wellhouse process, which has been used with the zinc-chloride treatment for many years, a small quantity of glue (usually about 0.5%) is added to the chloride solution, and there is a later application of a weak solution of tannin. This has been extensively used by the Atchison, Topeka & Santa Fe and Chicago, Rock Island & Pacific lines. With this process, the glue is solidified by the tannin and is rendered insoluble, stopping up the pores of the timber and preventing the escape of the salts from the timber by leaching. In districts where the rainfall is considerable this process is effective, and it is in use on about half of the roads where ties are chemically treated. Experiments have also been made with creosote instead of tannin and glue, following the zinc-chloride treatment.

There are a number of other preservatives, both patented and otherwise, which are put forward with various claims. Among these, creosote is undoubtedly the most conspicuous. It is well understood that creosote is a very effective preservative of timber, and it is known to be much more so than zinc-chloride, but it is so expensive in this country that its use for the treatment of railway ties on our railways has long been considered as prohibited. In England all ties are creosoted, and a life of about 16 years is obtained from Baltic pine timber. In France, where creosote is applied in larger quantities per cubic foot of timber than in England, the duration of the timber is much longer. Beech ties are made to last from 25 to 30 years. Some experimenting is being done with a view to utilizing creosote in an adulterated or weakened solution to lessen the expense. Various processes employing mixtures of zinc-chloride and creosote, water and creosote, chlorine gas and creosote, and resin and creosote, are being tried, in order to secure the benefits of this valuable material at available expense.

One experiment is now in progress on the Gulf, Colorado & Santa Fe Ry., near Waukegan, Tex. A large selection of timbers, including several varieties of pine and oak, besides hemlock and tamarack, have been treated with various well-known preservatives and laid in the track, together with untreated ties of the same kind of timber. A few years should determine the practical results of this experiment. It is being conducted under the supervision of the United States Department of Agriculture, and careful records are being kept of the service of the various kinds of timber that are being tried. The climate and soil at this point are so destructive to timber that untreated pine ties have decayed, it is said, in two years. This experiment was begun in the latter part of 1901.

Another important factor in prolonging the life of treated and untreated ties is their seasoning. It has been known for years that ties cut in the winter, and thoroughly dried before being laid in the track, hold spikes better and last longer than those cut at other seasons of the year and laid in the track before seasoning. The subject does not seem to have received the attention it should, but we believe that railway managers will find it a profitable investment to have all ties thoroughly seasoned before permitting them to be laid in the track.

METAL TIES.—Occasional experiments with metal ties in this country, in years past, have resulted in the general abandonment of the idea of such material for track support. The general verdict seems to be that track laid with such ties is expensive to maintain in surface, there being practical difficulties in the way of satisfactorily tamping such ties with ordinary track tools. It is to be noted, however, that they are successfully used in many other countries.

Some metal ties are now in use on the Bessemer & Lake Erie R. R., and are proving satisfactory. They are of inverted trough section with sloping sides. The top face is 5 ins. wide and the depth is 3½ ins. The ties weigh 208 lbs. each. The ballast is broken slag, and tamping is done by blowing pulverized slag under the ties by means of an air-blast machine. This machine is constructed by utilizing a blacksmith's blower, which is clamped to the rail and turned by two cranks on an upright frame. It was invented some years ago by the late Mr. Elisha Patterson.

An entirely different form of steel tie is in use on the Lake Shore & Michigan Southern Ry., and was designed by one of the Roadmasters, Mr. C. Buhrer. It embodies the feature of a flat bottom or face, buried in the ballast, as with wooden ties, thus permitting the use of the ordinary tamping bar or pick with equal facility, and just as effectively, as with wooden ties. This tie is of the I-beam section, there being a top flange about 4 ins. wide, which supports the track rail, and a bottom flange 8 ins. wide, which forms the under face of the tie. Ties of this shape have been used abroad. The track rail is attached to the tie by means of bolts and clips. The ties now in use are not of the above form; but each consists of a piece of inverted rail with a plate secured to the head to form the base or bottom flange. The track rail rests on the inverted rail. These ties are in the main track and they carry fast and heavy traffic. They are found to maintain the rails in rigid gage, and the track laid with these ties has been maintained in excellent surface and alinement at a cost for labor which is said to be only a small fraction of the usual expense required to maintain track laid with wooden ties.

During their service of three years these ties have not corroded to an appreciable extent. Some are in the yard at Sandusky, O., and others are in the main track about 2½ miles distant. The ties in the Sandusky yard have been exposed to drippings of salt water from refrigerator cars. Considering that ties thus exposed might appear at a disadvantage, so far as a test of durability under ordinary conditions was concerned, the tops were coated with a washing of thin cement mortar, which has adhered firmly and has served to completely protect the metal.

Mr. Buhrer has also experimented with insulation, with a view to ascertain the practicability of using metal ties, or ties with a metal top face, in connection with automatic block signals. Both wooden shims and fiber sheets, with fiber bushings for the bolts, have been tried, and, so far as these tests have shown, these materials have answered the purpose satisfactorily.

COMPOSITION TIES.—The high price of steel during recent years has turned attention to the use of concrete as a material for ties. The first experiment in this direction was with the Harrell tie, some of which were laid in the track of the Pittsburg, Ft. Wayne & Chicago Ry., in Chicago, in 1899. After a service of 1½ years, this tie failed, owing to defective designs. The Pere Marquette R. R. is experimenting with a tie of concrete and steel construction, designed by George H. Kimball, formerly Chief Engineer of that road. This tie consists of two bearing blocks of concrete, each 3 ft. long, 7 ins. deep and 9 ins. wide on the face. The blocks are used in pairs, one under each rail, and are united by two 3-in. steel channels molded in with the concrete blocks. A bearing for each rail is afforded by a 4 × 9-in. white oak block 18 ins. long, secured by bolts attached to the channel reinforcement and molded in with the concrete. The rails are spiked to these wooden blocks in the ordinary manner. Some of these ties have been in service since 1901.

The composite tie in most extensive use at the present time is from a design worked out and applied by Mr.

C. Buhrer, Roadmaster of the Lake Shore & Michigan Southern Ry. The reinforcement of this tie consists of a piece of scrap rail, corresponding to the length of the tie, inverted and molded in the top of the tie, the base or bottom part of the rail serving as the top face of the tie. The track rails are secured to this top face by means of bolts and clips. The ties are 6¼ ins. deep, with a base width of 9 ins., and the weight is 400 lbs. each. In order to economize in weight of material, the sides are hollowed out to some extent.

A piece of track 1,200 ft. long, on a compound curve running from 6 to 12°, on the Lake Side & Marblehead Ry., at Danbury, O., has been laid with these ties, and remarkable economy in the repairs and maintenance expense of this particular piece of track is said to have already been shown. At one end of this curve there is a turnout, and this was laid with concrete ties, to demonstrate the feasibility of using these ties in any place where wooden ties can be placed. Besides the roads named, this tie is also in use on the Wabash R. R. and the Pennsylvania lines.

CONCLUSIONS.—It is now generally recognized that the tie problem is getting to be a serious one, and that it will soon demand the attention of all railways, both in regard to the best character of tie to be used and the means of securing a future supply of ties. The wooden tie still holds its own in spite of the deterioration in quality of timber and the decrease in quantity of suitable timber, but steps will have to be taken to find new supplies of tie timbers, to increase the life of wooden ties (without too much increase in cost), and to find some satisfactory substitute for wooden ties.

In conclusion, your committee would state that at the present time three different lines of improvement in the production and use of ties are being followed or experimented with: (1) The treatment of wooden ties with chemical preservatives; (2) the use of ties made entirely of steel, and (3) the use of ties made of concrete reinforced with steel members embedded in the body of the tie. For the present it must be considered that the status of the steel market is an important factor in any question as to the use of all metal ties, and there seems to be little probability of their introduction. The chemical preservation of wooden ties and the use of reinforced concrete ties appear just now to be the most promising of practical results. Where the conditions of supply are such that wooden ties can still be obtained in desirable quantity and at reasonable cost, we would recommend treating with some of the processes using chloride of zinc as a means of extending the life and attaining an important economy. This may well be applied to the cheaper timbers which are of little use as ties unless treated. It would seem also that experiments with reinforced concrete ties may be undertaken with hope of success and ultimate economy.

J. E. McNeil, Chairman; W. M. Camp, J. B. Dickson, E. E. R. Tratman.

SUPPLEMENTARY REPORT.

The use of wooden ties is now universal in this country, and it is likely to continue for very many years. Various substitutes have been suggested and a few have been tried in this country; but the cost, the uncertain results, and the general availability of timber, have prevented their introduction except to an extremely limited extent. Of 205,000 miles of railway (and 275,000 miles of track) in the United States, it is safe to say that not five miles are laid with any but wooden ties. It is therefore with the wooden tie alone that the railways and the roadmasters have any extensive experience, and the only tie with which they have to deal. With an increasing demand and decreasing supply it is becoming more and more important to get the best possible service from these wooden ties.

In saying this, it is not intended to throw cold water upon experiments with substitutes for wooden ties, but it is perfectly evident that while interesting experiments have been made and are being continued, these substitutes are not a practical consideration in this country at the present time. Railways in other countries have in all about 235,000 miles of track laid with metal ties of various forms, and in a majority of cases these have been quite satisfactory, while in very many cases they carry fast and heavy traffic. One of the best features of the modern steel ties is that they have a permanent and efficient rail fastening, far superior to the spike. Concrete ties are used to a limited extent in this country and abroad, but they are too few and their service has been too short to enable any definite statement to be made as to their practical value.

SUPPLY OF TIMBER.—While there is plenty of timber to be had, and while the price for good ties is still low enough to keep the ties of other materials out of practical consideration, yet it is a well known fact that the supply of really good tie timber is diminishing and its price is advancing. Some railways are having investigations made as to the location of and capacity of new sources of supply of first-class tie timber. Other railways are investigating the sources of supply of timber which, while inferior if used without treatment, may be given a preservative treatment to make them give as good service as untreated ties of first-class hard wood timber, and at less cost.

RECORDS OF TIE RENEWALS.—One of the greatest difficulties in reducing the use of ties to a commercial and economical basis is the absolute lack of information or knowledge as to the service of the ties. Each year ties are purchased, inspected, distributed over the road and used in renewals. After these have been in the track a few months they lose their identity, and on very few roads is it possible to say of any lot of ties where they are, what they cost, how long they have been in use, where they came from, or when they were laid. Consequently, when old ties are removed, it is impossible to give this information about them, and this makes it impossible to determine their real efficiency and economy as measured in dollars and cents and work done.

Several roads are making a beginning in the keeping of records of tie renewals and marking their new ties with dating nails, so that their length of service in the track can be ascertained at any time. The use of these nails is much more reliable than notching or stamping the wood. This is, however, only a beginning. It will be years before the practice is general, and before any definite information can be drawn from a comparison of the records. But this is really a most important matter. Having purchased a lot of ties, it should be possible to know at least if they are giving good or bad service. But under the present system they are soon lost sight of in the track, and it is almost impossible to find out anything about them. The great majority of American railways still continue to use ties in a reckless manner, maintaining little supervision over them when once they have been laid in the track, and keeping no effective record or account of comparative cost, service and ultimate economy.

SEASONING OF TIES.—It is well known that timber which has been seasoned is much more durable than the same timber put into service while still green. The process of seasoning ties is almost universally employed by railways in Europe, but in this country it has been very much neglected in regard to railway ties, thus losing much of their value by the neglect of a simple and inexpensive treatment. There is of course the cost of handling the ties, the loss of interest on investment while stored, and the risk of possible loss of the ties by burning, etc., to be considered. But it is pretty certain that the ultimate saving due to increased life and value will far outweigh these considerations. Seasoning is advisable for all ties, whether they are to be treated or not. For ties treated with preservatives consisting of chemicals dissolved in water, a further seasoning after the treatment is advisable, to allow the water to evaporate and leave the chemicals fixed in the wood fiber. This second seasoning should be for two or three months in summer and longer in winter.

At the preserving works of the Chicago, Burlington & Quincy Ry., at Sheridan, Wyo., experiments have been made with the seasoning of ties before and after treatment. The ties were stacked in different ways, and weighed periodically to determine the amount of evaporation. It has been found that the most rapid evaporation or seasoning is secured with ties piled in stacks with alternate rows of two ties and seven ties.

PRESERVATIVE TREATMENT OF TIES.—There is no doubt whatever that preservative treatment increases the life of ties, and makes ties of cheap inferior timber as good as, and often more economical than, untreated ties of first-class timber. On the Chicago, Burlington & Quincy Ry. the average life of pine ties is about five years (in Wyoming and South Dakota) while the indications are that the treated ties will last fully ten years. The zinc-chloride or burnetizing process is used, giving ½-lb. of zinc chloride per cu. ft. of timber. The record of treated ties taken out of the tracks of the Atchison, Topeka & Santa Fe Ry. during five years show an average life of over 10 years. On the Chicago, Rock Island & Pacific Ry. the treated ties removed in 1901 had an average life of 10.66 years on the lines east of the Missouri River and 11.66 years west of the Missouri River.

The preservative treatment should not be considered alone, however. The ties should be properly seasoned before and after treatment, and if they are liable to be cut by the rail they should be protected by metal or other tie-plates, so that the tie may not be cut out and rendered useless while still sound and durable. Treated ties removed for rail cutting do not give the full economy due to their treatment. It is very much to be desired also that an improved rail fastening could be introduced, and so save the spike killing of ties.

CONCLUSIONS.—It has already been pointed out that in view of the conditions of timber supply and consumption in this country, we may expect a future development in the introduction of steel or concrete ties for general use, not as purely experimental. It is therefore well that this future possibility should be considered, and experiments made in this direction.

But it is very evident that while substitutes for wooden ties are to be regarded with interest as future possibilities, they do not to-day enter into the practical considerations of either construction or maintenance. The roadmaster and the roadway department have wooden ties in the track, and are given wooden ties for renewals. It is of more importance for them at this time to consider the best means of using these wooden ties and getting the best service out of them. With the increasing price and the decreasing supply of hardwood ties, the preservative processes become of great importance in introducing a supply of ties practically as good as hardwood ties at the same or lower cost. Every tie costs a price and should be made to give its full service by the aid of proper ballasting, tie-plating, etc.

The aims of the roadway department should be as follows: (1) To have ties of proper material; (2) to subject them to seasoning or preservative processes to put them in the best condition for service; (3) to mark all the ties; (4) to keep them in use to the full extent of their life; (5) to keep a record of their life and performance; and (6) to keep a system of accounts showing the cost and life of ties from year to year. With such systematic management there will be less money wasted and more knowledge of what return is got for the money spent. There will also be less waste of good timber and a more economical use of the timber that is properly employed for railway ties. —E. E. R. Tratman.*

PRESERVATION AND PROTECTION OF TIES.

An address on this subject was delivered by Mr. Hermann von Schrenk, of the U. S. Department of Agriculture, in which reference was made to the work of the department in investigating the possibilities of timber lands owned by railway companies, and advising as to the purchase of other lands on which to secure a permanent supply of ties by adopting proper forestry methods. Among the railways which have requested such investigations are the New York Central R. R., the Pennsylvania R. R. and the New York, New Haven & Hartford R. R. The preservative treatment of ties to protect them from decay was then referred to, but Mr. von Schrenk laid particular stress upon the importance of protecting them from wear and mechanical destruction. Without this protection, the preservative treatment may be very uneconomical and perhaps useless. Among these protective measures are tie-plates, and S-shaped pieces of hoop-iron driven into the ends of ties to prevent cracking and splitting. Metal tie-plates are most generally used, but on European railways tie-plates of thin sheets of poplar and compressed felt are quite extensively used to protect treated ties from abrasion due to the movements of the rails. The poplar plates last two years under 90-lb. rails, and it is much more economical to wear out these cheap tie-plates than to wear out a tie which has been treated at some expense. The use of screw spikes or lag screws was also advocated as a means of protecting the ties from abrasion by the rails (due to holding the rails rigidly to the ties) and from spike-killing (due to the continual working up and driving down of the ordinary spikes). Some experiments with screw spikes failed owing to the use of material of insufficient strength, the rails bursting off the heads of the spikes. At the present time, however, about twelve of the important trunk lines are arranging to make extensive trials of screw spikes. Several specimens of foreign screw spikes and wooden plugs for spike holes were exhibited.

DISCUSSION.

The discussion was opened by Mr. Goldie, who, as an inventor and manufacturer of spikes, naturally favored the ordinary type of spike as against the screw spike or any other type of fastening. In support of this view he remarked that on some European roads having steel ties bolted rigidly to the rails the ties lifted in the ballast under passing trains and so tended to grind the ballast to powder. He admitted, however, that track was maintained in better gage than in this country. He suggested the obsolete idea that spikes should be so driven as to leave a clearance between the spike head and rail base, a method which was experimented with long ago. Mr. Camp ("Railway Review") stated that the Prussian State Railways were experimenting with loose fastenings on this plan, but nothing was said as to the weight of rail used. Mr. Buhrer and other roadmasters opposed the idea that loose fastenings were in any way desirable, and the satisfactory results obtained with tightly bolted fastenings were referred to.

As to treated ties, Mr. Meade (Res. Engr.; A. T. & S. F. Ry.) said that ties which lasted only four years when untreated, averaged 10.18 to 10.58 years when treated, the cost of treatment being 13 cts. per tie. In reply to a statement that treated ties were not giving good results in damp districts and ill-drained track on the Burlington & Missouri River R. R., it was pointed out that these ties were treated with the bur-

*Associate Editor, Engineering News.

netizing process, which allows the zinc solution to leach out in damp ballast. This objection does not apply to the Wellhouse process, by which the wood cells are sealed against moisture. Mr. McEniry doubted the accuracy of the statement made in the report giving the average life of treated ties on the Chicago, Rock Island & Pacific Ry. at over 10 years. He said that many foremen reported treated ties as lasting little if any longer than untreated ties. He admitted, however, that many of these ties were not only green when treated but had been treated with the bark on, and as the bark retains a large proportion of the preservative and soon becomes stripped from the tie, the wood itself is very imperfectly treated. As to concrete ties carrying derailed trains, he thought they would be liable to be knocked to pieces. Wooden ties sometimes carry derailed wheels, but at other times they are smashed and have to be renewed. Mr. Morrison remarked that the cost of renewing ties depends largely upon the traffic, and where the traffic is extremely heavy the actual cost may run up to 50 cts. or $1 per tie.

Mr. C. E. Jones (C. B. & Q. Ry.) said that his road was awake to the seriousness of the tie question and has not only purchased 150,000 treated red-oak ties (which wood is practically useless unless treated), but has also undertaken the manufacture of 1,000 concrete ties. A roadmaster of the A., T. & S. F. Ry. lines in Texas said that he had had experience with thousands of treated ties, and only a very few had been renewed. In most cases these renewals were due to the wood having been rotten or defective before treatment, or to its being so over-treated or "cooked" as to damage it. Mr. Tratman (Engineering News) pointed out that failure of treated ties usually results from the use of defective timber or improper treatment in the preservative process. The failure of ties treated when green and with the bark on was naturally to be expected, and it was probably a waste of money to treat such ties. As to the C., R. I. & P. Ry., the official records sustain the figures given in the report. These figures are for the entire system, and cannot be compared with results stated by foremen on sections only a few miles in length. In the reports presented the committee had pointed out the necessity of properly seasoning the wood to be treated, and also the lack of economy in improperly treating ties.

METHODS AND COST OF CONSTRUCTING A CONCRETE SEWER HAVING A BRICK ARCH, AT MEDFORD, MASS.

The construction of a 30-in. sewer, Fig. 1, involving some novel features, is described in the last annual report of Mr. William G. Taylor, City Engineer, of Medford, Mass. The work was done by day labor, so that a record was kept of the actual cost of construction. It will be observed from the abstracts that follow that common labor was paid 25 cts. an hour, which is an unusually high price.

Mr. Taylor has kindly furnished us with photographs of the novel centering used, which, taken with the abstracts from the report, make clear the method of construction. That part of his report relating to this sewer is given in full as follows:

The sectional plan and equipment for constructing the sewer were designed, during the early summer, along original lines. The material chosen for the invert and

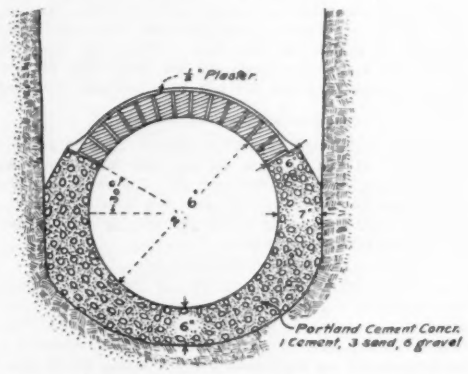


Fig. 1. Cross-Section of Concrete Sewer Having a Brick Arch.

haunches was Portland cement concrete masonry, having a proportion of one part cement, three parts sand and six parts bank gravel. The arch was formed of a single ring of hard-burned sewer bricks. The forms were so designed that the concrete haunches extended up to a plane 30° above the horizontal. This made a material reduction in the amount of brick work necessary and a consequent saving in expense, as brick masonry under existing conditions costs twice as much as the concrete work, but to accomplish this special forms for molding the sewer were necessary.

The style of forms adopted is shown in Fig. 2. They were 10 ft. long and made in halves separating on a vertical line through their center, and were securely held together by means of malleable iron clamps gripping the stringers along the inner edge of each sectional form. Proper width and stiffness were obtained by inserting an iron dog in the end ribs of each 10-ft. section. In using these forms they were first smeared to prevent the cement from sticking to the woodwork; they were then set up in the trench, Fig. 3, to the exact line and grade and the fresh concrete deposited about them. The next morning these forms were removed from the concrete one after another by knocking out the iron dogs in each end of the forms and putting in place thereof turnbuckle hooks. After releasing the iron clamps the turnbuckles were turned so that the upper portion of the forms approached each other slightly, thereby separating them from the concrete work in a most careful way. The concrete invert and haunches were thus formed in a perfect manner, and the inner surface of the drain was in all cases as smooth as the planed surface of the form.

Upon the removal of the forms the concrete was allowed to remain exposed to the air until the expiration of 24 hours, when the arch centers were set up in place and the brick arch turned and plastered. These arch centers, Fig. 4, were made in 10-ft. lengths, of ⅞-in. lagging, 2-in. plank ribs and stout stringers on each side. All lagging was 1½ ins. wide and milled so as to have one beveled edge, in order that the exterior surface might be planed very smooth. The ribs in all forms were spaced 2 ft. on centers. On the forward end of the arch centers there was securely fastened to each side a stout wooden wedge, which supported the rear end of the next center. It was then necessary to provide only one movable support for each 10 ft. of arch centers. In putting these arch centers in place a man stood upon the skewbacks, raising the center with an iron hook which passed through a small hole in its top, while a man at the forward end pushed it into place upon the wedges of the preceding center. The forward end of each center was supported by a patent screw brace or jack placed under a rib 2 ft. from the front end.

After the single ring brick arch had ben turned and the mortar sufficiently set, the arch centers were removed by the aid of a special truck, shown in Fig. 5, which had two bent axles and four cast-iron wheels so adjusted that they ran smothly along the concrete invert. At each end of this truck was a long rope. In the removal of the arch centers, an adjustable roller was first fastened by means of a thumb screw to the outer rib, then the truck was pulled a foot or more under the center, the screw jack was released, allowing the forward end of the center to drop about an inch, upon the running board of the truck, which was pulled into the drain until the adjustable roller ran off the rear end of the truck, automatically locking itself there, whereupon the tail rope was pulled by a man outside the finished sewer, drawing the arch center off its supporting wedges and allowing it to drop upon the truck to be wheeled to the outer end of the work.

In this manner the arch centers were set up in place and were very rapidly removed without the least injury to the comparatively fresh concrete.

All the work was performed by day labor by citizens of Medford, working eight hours a day at a standard daily wage of two dollars.

DETAILED COST OF 30-IN. MASONRY SEWER (1,610 FT. LONG).

Each linear foot of sewer required 1.25 cu. yds. excavation and refill, 4 cu. ft. Portland cement concrete, and 1 cu. ft. brick masonry.

Excavation and Refill.

Excavation	$677.84
Bracing	52.47
Backfilling and resurfacing street	335.84
Pumping	1.00
Water boy	33.90
Kerosene	17.28
Boots	2.35
Lumber	69.00
Total	$1,189.68

Material excavated was gravel and clay.
Total volume excavated, 2,019 cu. yds.
Cost of excavation and refill was $0.589 per cu. yd.

Concrete Masonry.

Portland cement, 256¼ barrels	$550.27
Labor, mixing and depositing 240 cu. yds.	723.92
Cost of forms	45.00
Screening gravel (labor)	112.63
Gravel and sand purchased (gravel and sand mostly taken from excavation)	14.00
Carting	142.38
Miscellaneous items	21.32
Total	$1,609.52

Total cubic yards of concrete, 240.
Cost of concrete, $6.70 per cubic yard.

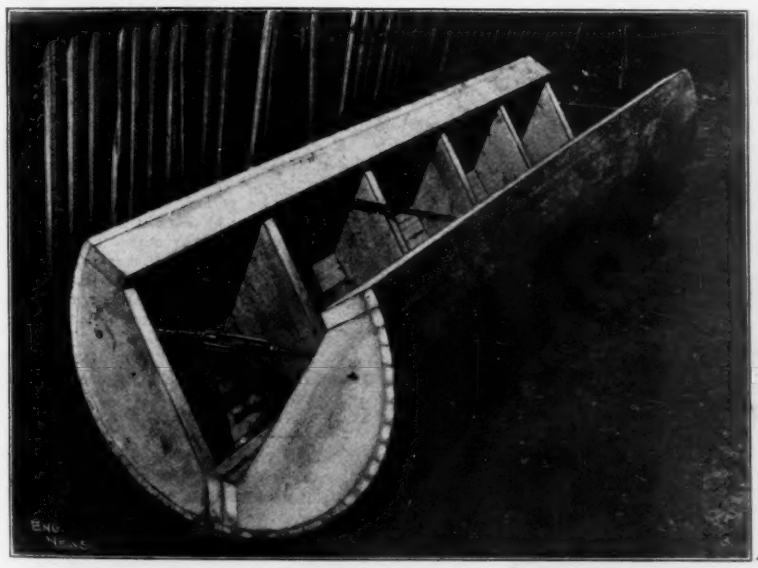


FIG. 2. HINGED FORM FOR INVERT OF CONCRETE-BRICK SEWER.

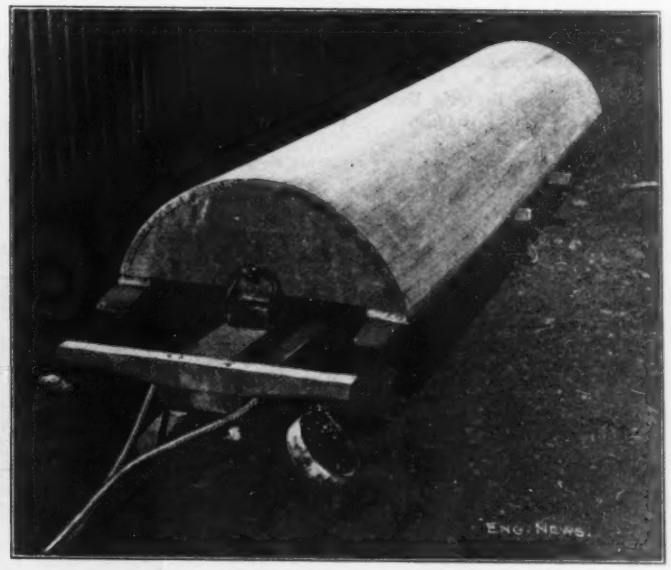


FIG. 5. TRUCK FOR SHIFTING ARCH CENTER OF CONCRETE-BRICK SEWER.

Brick Masonry in Arch.

Portland cement, 79 barrels		$178.54
Brick, 29,000		246.50
Forms		23.73
Labor, mason	$79 20	
Tenders	123.25	
		202.45
Carting		40 00
Incidentals		20.12
Total		$711.34

Total cubic yards brick masonry, 59.
Cost of brickwork in arch, $12.05 per cu. yd.
Cost of brickwork in manholes, $15.34 per cu. yd.

It is interesting and valuable to compare the cost of this sewer with that of a pipe structure of equal diameter. To do this it is necessary to deduct the fixed charges from the total cost of the work.

By fixed charges is meant those items which would remain unchanged whether a masonry structure or a pipe sewer was constructed:

Fig. 3. Hinged Form in Use in Concrete-Brick Sewer.

Total cost of work	$3,847.11

Fixed Charges.

Excavation and refill, tide gates, seats, manholes and appurtenances, etc.	$1,526.25
Leaving for variable items	$2,320.86

The total cost minus the fixed charges leaves $2,320.86 as the amount of the variable items. This is also the net cost of the masonry structure, and when divided by the length, 1,610 ft., gives $1.44 as the cost of the sewer per linear foot. Compare this with the price of 30-in. sewer pipe, list $5.50 per ft., less 60% discount, leaving a net cost of $2.20 per linear ft. on the freight cars. To this must be added the cost of cartage, handling and laying.

Not only is the masonry structure much cheaper than the usual pipe sewer, but it is stronger, smoother, and has, therefore, greater carrying capacity, and offers greater resistance to the entrance of roots.

THE RIVETED STEEL PIPE LINES of the water supply of Newark, N. J., were subjected to severe strains at some points during the heavy rainfall and floods in the early part of last October. For a number of miles below the Macopin intake, on the Pequannock River, there is a double line of 48-in. pipe; one was laid in 1891 and the other in 1896. About 1½ miles below the intake these conduits were undermined and left unsupported for a length of about 35 ft. The pipe sustained without apparent injury not only the weight of water flowing through them at the rate of some 50,000,000 gallons a day, but also a large number of uprooted trees that lodged against them. Only some 50 ft. away the conduits passed through one of the abutments of a culvert, the foundations of which were washed away, leaving the abutment partly supported, it is said, by the pipes. At still another place the river broke through a bank built to divert it, laid bare more than 50 ft. of the double line of pipe laid in the old bed, and poured over the conduits without injury to the latter. The question naturally rises, what would have happened had cast-iron pipe been left unsupported as were these lines of riveted steel conduits? Doubtless the effect would have been to cut off the water supply of Newark. To guard against just such a contingency a large storage reservoir is now being built near Montclair, a few miles from Newark, and an independent riveted steel pipe line, 60 ins. in diameter, is being laid from the reservoir to the city. The foregoing statements regarding the old conduits have been taken from an illustrated pamphlet published by the T. A. Gillespie Co., 71 Broadway, New York City, who were the contractors for both conduits.

THE COCKERILL GAS ENGINE, built by the famous John Cockerill Co., of Seraing, Belgium, is to be manufactured in the United States by the Wellman-Seaver-Morgan Co., of Cleveland, O., which firm has secured the United States rights of the Cockerill Co. The Cockerill Co. has led the world in the manufacture of gas engines for using blast furnace gas. At the Paris Exposition in 1900 this firm exhibited a 700-HP. engine, which was illustrated in Engineering News of July 19, 1900. At that date the company and its licensees had built and under contract 71 engines of this type. While the Cockerill engine has been built chiefly for use with blast furnace gas, it is also adaptable for use with producer or other gas.

A HIGH-HEAD CENTRIFUGAL PUMP, to work against a pressure of 250 lbs. per sq. in., has been developed by the firm of Henry R. Worthington. The pump is of the multi-stage reversed turbine type and one with a capacity of 500 gallons of water per minute will be exhibited at St. Louis next year.

AN ESTIMATE OF THE COST OF THE CAST-IRON mains forming a part of the water-works system of Richmond, Va., was made not long ago by Mr. Dabney H. Maury, M. Am. Soc. C. E., of Richmond, Va., as a basis for determining the depreciation of the mains due to electrolysis. The estimate was included in a report to the city authorities of Richmond, the main conclusions of which report were given on p. 422 of our issue for Nov. 5, 1903. We publish herewith a table from the same report giving in some detail the basis of Mr. Maury's estimates of the cost of the mains in place, before any pavements had been laid:

Estimated Cost of Cast-Iron Mains of Water-Works at Richmond, Va., Before the Pavement Was Laid.

Size, ins.	3	4	6	8	10	12	16	20	24	30
Thickness, ins.	13/32	13/32	7/16	15/32	1/2	17/32	21/32	7/8	29/32	31/32
Weight, per lin. ft., lbs.	15	20	30	42	56	74	112	183	225	300
Cost, pipe (inspection and hauling), lin. ft.	$0.234	$0.312	$0.468	$0.655	$0.874	$1.154	$1.747	$2.75	$3.38	$4.50
Lead, per lb.	.0245	.0333	.050	.062	.083	.10	.133	.163	.175	.244
Yarn	.0005	.0007	.001	.001	.002	.003	.004	.005	.007	.011
Gates, gate boxes and specials	.036	.038	.045	.05	.064	.084	.125	.172	.238	.265
Hydrants and hydrant branches	...	.06	.06	.06	.06	.06	.06	.06	...	...
Labor	.235	.286	.286	.312	.387	.439	.53	.68	.85	1.05
Insurance, depreciation on tools, plant, etc.	.07	.09	.09	.11	.13	.16	.20	.27	.35	.43
Total	$0.60	$0.75	$1.00	$1.25	$1.60	$2.00	$2.80	$4.10	$5.00	$6.50

A LARGE CONCRETE ARCH CULVERT has just been completed near Mingo Junction, Ohio, on the new Pittsburg, Carnegie & Western R. R., a branch of the Wabash system. The span of the arch is 50 ft. and the length of the barrel is 118 ft. The side walls are 20 ft. thick at the base, and the crown is 4½ ft. thick. For the forms and centers 150 M. ft. of lumber were used. A Climax crusher

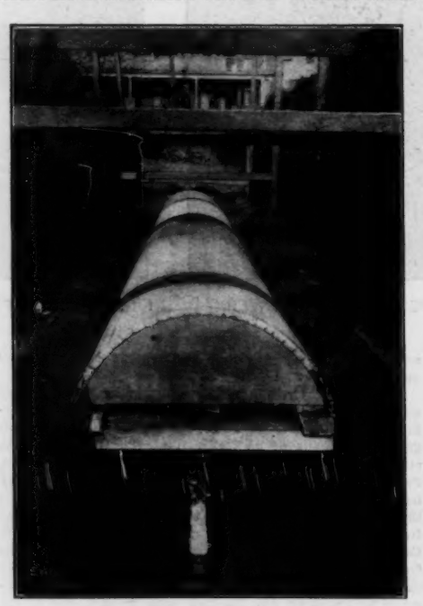


Fig. 4. Center for Brick Arch of Concrete-Brick Sewer.

and a 4-ft. cubical mixer were used by the contractors, Scott Bros., the concrete being delivered from the mixer into a wooden box that sat on a small car. The car was pushed by two tagmen to where a derrick could be hooked on. Four derricks were used, two on each side of the culvert. The concrete boxes, of which there were three, were provided with drop bottoms and latches. More than 8,000 barrels of Portland cement were used in the construction of this arch. In our issue of May 21, 1903, photographs are shown and other features of this concrete arch work described.

THE MOST SERIOUS RAILWAY ACCIDENT of the week was a rear collision on the Illinois Central Ry. at Kentwood, La., on Nov. 14. A through express train, north-bound from New Orleans to Chicago, ran at high speed into the rear end of an accommodation train which was filled with passengers, most of them section hands who had been picked up at various points along the road. The two rear cars of this train were split and completely destroyed. The wreck took fire and in consequence the exact number of victims is difficult to determine. It is certain, however, that at least thirty persons were killed, all but one or two of whom were passengers in the two rear cars of the accommodation. The engine of the express train was damaged, but the rest of the train was not affected. The responsibility for the accident is not yet fixed. Both trains were off their exact time, the accommodation train being three-quarters of an hour behind. The blame for the collision will fall either on the dispatchers or on the engineer of the express. The latter claims to have had a clear track, while one station operator claims to have displayed a station-stop signal.—Another uncommonly serious wreck is to be recorded. On Nov. 12 two freight trains on the Louisville & Nashville Ry. collided head-on near New Hope, Ky. One of the engines was double-headed; all three engines were destroyed and the six men of the engine crews were killed, while several others of the trainmen were dangerously injured. The collision occurred in heavy fog, on a reverse curve on high embankment; both trains went down the embankment.

A NEW RAILWAY FROM PITTSBURG TO NEW YORK is being surveyed, according to newspaper reports. The route is said to be 73 miles shorter than that of the Pennsylvania R. R. The engineering corps is now at work in the southern part of Centre County, Pa. The line, it is said, will cross Warren, Morris and Essex counties, N. J. There are various rumors as to who is back of this railway project; by some it is said to be an extension of the Wabash system; by others it is regarded as an extension of the Erie system. It may be remarked that under present financial conditions it is a very far cry from such surveys as are noted above to actual construction of a new trunk line railway.

THE CONVENTION OF THE UPPER MISSISSIPPI Improvement Association has adopted a memorial asking Congress to appropriate $15,000,000 for the dredging of a 6-ft. channel from St. Paul to the mouth of the Ohio.

COTTON EXPORTS from the United States for the month of October averaged $2,000,000 per day in value, according to the statistics collected by the Department of Commerce and Labor. In the 12 months ending with October the total value of cotton exported was $320,406,000. This is a larger total than has ever before been recorded.

TO PREVENT PIPING IN STEEL INGOTS a new method has been advanced, which does not involve compressing the ingot during solidification. The principle of the method is to allow for the escape of the gases in the steel, and for the necessary shrinkage during solidification, by keeping the upper part of the ingot in a fluid condition until after the larger part of the ingot has solidified. To accomplish this, a burner cap is placed on the top of the ingot mold, and a gas blast-flame is directed downward upon the metal in the mold; vent-holes at the sides of the cap provide for the escape of the gases. The flame is so proportioned as to keep the upper part of the ingot considerably above the melting temperature, thereby causing the ingot to solidify progressively upward. The metal can thus follow the contraction in volume and the gases in the metal can freely escape. Sections taken from ingots cast with the use of this method show a very small depth of honeycombing at the top, and uniformly sound metal below this. The crop-end can be reduced to less than 10% of the ingot by this means. The gas and air supplied to the burner must be preheated so as to produce the highest possible flame-temperature. The cost of using this method is said to be very low. The method has been patented by a German, Mr. J. Riemer. It is described more at length in a recent number of "Stahl und Eisen."